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STUDY ON THE FEASIBILITY OF MASS AREA ORDNANCE DECONTAMINATION

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The problem of clearing subsurface unexploded ordnance from military target ranges and impact zones present the major obstacle to effective decontamination of these areas. This report has identified the information needs and delineated the capability deficiencies as they relate to range clearance. An R&D program was formulated for EOD joint service implementation that could provide the fleet/field operator with the means to conduct effective range decontamination in the immediate and mid-range time frame. The general lack of adequate range records and descriptive physical data continues to limit the analysis of actual range contamination and development of comprehensive clearance plans, particularly with regard to subsurface ordnance.

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SECTION I

A. INTRODUCTION

1. Background and Issues. Recent emphasis on land reclamation by the state and federal governments and Congress has placed considerable pressure on the military services to return certain properties to civil authorities. Many of these areas have been used as target ranges or ordnance impact zones and as a result have been subjected to bombardment by practically all types of military ordnance. There are currently no proven methods of massive decontamination which will assure complete sanitization of an area, provide for ecological constraints and allow for "certification of clearance."

This study addresses the problem of clearing the sub surface (buried) ordnance from these target ranges and impact zones. The basic research objective was to determine the feasibility of developing new and more effective methods for explosive ordnance clearance operations. Work was conducted under contract N00174-74-C-0177 for the U.S. Naval Explosive Ordnance Disposal Facility, Indian Head, Maryland.

2. Study Scope. As a feasibility study, primary emphasis was placed on defining the problem relative to determining the feasibility of developing a mass area clearance system. This required that the study: (1) identify informational gaps and capability voids and (2) design a proposed R&D program responsive to field operator needs in the immediate and mid-range time frame. The stated objectives were to:

a. delineate the problem as it relates to operational requirements which will involve the joint-service EOD organization in the near time frame (1975-1980);

b. determine relative utility of equipment, tools and materials currently available to the EOD community for the accomplishment of range clearance;

c. collect first-hand information from the operating community on current needs and recommended areas for R&D to improve overall range clearance capabilities;

d. review equipment and programs in both industry and the military that might relate to (or have a predictable spin-off in) the areas of detection/ location and disposal of buried ordnance; and

e. propose an R&D program, including a recommended plan for implementation, which is responsive to both the current and projected operational requirements to conduct subsurface clearance of explosive ordnance.

3. Data Collection. Data collection was accomplished through extensive literature search, interviews with key personnel and visits to operational and R&D installations. These visits included discussions and facility tours at:

- 2701st Explosive Ordnance Disposal Squadron, Hill Air Force Base, Utah;
- Picatinny Arsenal, Dover, New Jersey;
- The Defence EOD School, Camp Lodge Hill, Chattendon, England;

- Maplin Sands, Shoeburyness, Essex, England;
- Llanberis, Wales;
- RAF 71st EOD(BD) Flight, RAF Bicester, Oxford;

and the various service liaison detachments at the EOD Facility, Indian Head. The discussions and briefings conducted during the above visits provided an extensive overview of recent employment, operating procedures, and problem areas including field expedient solutions. The United Kingdom visit provided the opportunity to observe actual mass area clearance operations at Maplin Sands and Llanberis. Even more significant were the discussions with field operators who are actually engaged in a systematic subsurface clearance of large, heavily contaminated areas.

B. SUMMARY

1. Brief Statement of Results. The results are summarized below under the four major categories which were addressed in the study;

• Problem Definition - The problem definition phase determined that current range survey data was not sufficiently comprehensive to allow for detailed analysis. There is in excess of ten million acres of joint service range land which has been subjected to varying degrees of contamination. The Navy has developed a range clearance plan which included range survey information. However, the plan recognized the need for additional information and recommended a comprehensive range survey program. Implicit in the problem of area clearance is the need for detailed data on range characteristics, usage and degree of contamination.

• Impact Range Characteristics - The range survey data which was available to the study was analyzed to determine identifiable characteristics of various military range areas and assess the effect of these characteristics on mass area clearance. Range comparison indicated that a majority of ranges are relatively flat with low ground cover and are contaminated with a wide variety of ordnance. Extensive variations were found in soil strata composition and type of ground cover. The physical characteristics of a range represent the "X" factor in determining the penetration depth of impacted ordnance. The survey data and observation of experienced range personnel tend to contradict analytical predictions of ordnance penetration. It is postulated that soil profiles have a significant effect on impacting ordnance. This would account for the apparent differences between analytical predictions and actual observations.

• Clearance Operations - Range clearance operations involve a series of sequential and systematic actions that are closely interrelated. Area surveys are essential to proper planning and a determination of the type of clearance required. The essential elements of an area survey include physical characteristics of the range, ordnance classification and delivery methods, range usage data or estimate of contamination, proximity of populated areas.

Analysis of the clearance sequence and procedures indicated that heavy equipment of proper design can contribute significantly to the effectiveness of subsurface range clearance.

Land restoration is a major consideration if the area to be cleared has been designated for civilian use. The land reclamation laws of most states dictate as a minimum that an area be backfilled and recontoured.

A selection criteria for clearance methods was developed; the primary factors involve size of area, distribution of ordnance, ordnance classification, physical characteristics of area, climatic considerations, desired clearance rate and area volume to be cleared.

The need for continual range data collection cannot be overemphasized. Current methods are inadequate, obsolete or non-existent. A range data collection system must allow for the dynamic character of range utilization. The management of impact ordnance ranges, and subsequent ordnance decontamination, would be enhanced considerably by the systematic recording of events and the application of interrelated data to provide predictive location of impacted ordnance.

- Survey of Earth-Moving Equipment - A survey of the performance characteristics of current mining and construction equipment indicated that their unique capabilities might be incorporated in a simplified design which is applicable to range clearance. Despite the high acquisition cost of major machinery, their hour/area cleared operating costs are surprisingly low when compared to man-hour costs. The dragline concept appears to be uniquely suited to area decontamination operation. It was also determined that with minor modification several vehicles in the military inventory, such as tank retrievers and the rough terrain crane, could be employed in range clearance in a limited capacity.

• R&D Program for Range Clearance - Current range clearance procedures involve personnel-intensive operations wherein each individual piece of ordnance must be located, accessed and detonated in place, or removed for disposal at a remote location. A mass removal and disposal capability can significantly reduce the personnel requirements, hazardous exposure times and total costs. Related subsystems that would comprise the total system such as, mass munitions disposal, detection/location, access/retrieval and support equipment are currently under various stages of development. Accordingly, an R&D program for the development of a RECOVERY/REMOVAL SUBSYSTEM is proposed. This subsystem will interface with and contribute to the effectiveness of the related subsystems.

2. Conclusions. The conclusions are titled to facilitate reference to the analysis section. There is no significance inferred by the order in which they are presented. Based on the study results, it is concluded that:

• PROBLEM DEFINITION

The scope of the range clearance problem is significant, however, detailed analysis cannot be accomplished from the information which is currently available. Range usage data is incomplete or nonexistent. The total area of contaminated land, the degree of contamination, the type of ordnance involved and the physical characteristics of each range must be recorded for all military impact areas.

• CLEARANCE PROCEDURES

Current procedures and equipment are not adequate for the accomplishment of mass area

decontamination. They involve personnel-intensive operations using hand held equipment to detect, locate and retrieve or dispose of impacted ordnance. These procedures are time-consuming, costly and result in undue exposure of personnel to hazardous conditions. Safety and effectiveness could be improved by the introduction of machine methods.

- AREA SURVEY

There is a need for a comprehensive and continuing range survey program. Many of the contamination areas are saturated with practically every type of explosive ordnance which has been used by the U.S. Military, including test and foreign items. To properly plan for current and future range clearance operations and determine cost, equipment and personnel requirements, detailed information is required.

- DATA COLLECTION

A range data collection system should be implemented which is responsive to the dynamic nature of range usage. This data is vital to EOD clearance operations. The time involved in survey and reconnaissance of each range prior to clearance could be reduced to a minimum if real time information was available as to the extent and nature of contamination.

- EQUIPMENT SURVEY

There are various types of mining and construction equipment which have application to range clearance. The survey of earth-moving equipment indicated that excavation machinery may be particularly

well suited to area decontamination. The dragline principle has unique application to ordnance recovery and removal and with minor modification would provide a significant improvement in capability. There are several military vehicles such as the tank retriever and rough terrain crane that could be employed in range clearance with minor modification.

• COST ANALYSIS

The acquisition cost of major mining and construction machinery is high. However, the cost of operation is not prohibitive when compared to man hour costs. The hour/area cleared operating costs may be as low as one fifth the cost of using personnel to clear an equivalent area.

• PENETRATION DATA

Current analytical data on bomb and projectile penetration should be statistically verified. The most unpredictable factor in planning for range clearance operations involves the estimative process for determining the extent of subsurface contamination. Current analytical tables provide predictive depths that are not always consistent with range survey reports or the observations of experienced EOD personnel.

• R&D PROGRAM

The current R&D program does not provide for the development of an area decontamination system to support range clearance. The range clearance requirements must be documented by all services to allow for the establishment of a responsive

program. Hardware analysis should continue under exploratory development to provide a conceptual design for a recovery/removal subsystem. This subsystem would significantly improve current capabilities and contribute to the development of related systems.

3. Recommendations. On the basis of the study it is recommended that:

- All services initiate a comprehensive and continuing range survey program to gather the data which is necessary for developing a range clearance plan; and, that the Navy revise and update their Ordnance Clearance Plan.

- Concurrent with the survey each service determine those ranges which may be subject to real property disposal and subsurface decontamination in the 1975 to 1980 time frame to provide meaningful statistics relative to the immediate problem.

- A joint service range data collection system be established to include the above survey results and record range usage on an as-occurring basis.

- Joint service procedures for EOD range clearance operations be promulgated to clarify responsibilities, and standardize procedures and certification.

- Bomb and projectile penetration tests be conducted to collect empirical data on the penetration parameters of a representative sampling of munitions in various soil types. The test program should emphasize data collection on the effect of soil stratification and surface vegetation.

• A representative range area be selected for an exhaustive site survey. The resultant data can be used to develop a prototype design for a removal/ recovery subsystem; establish design to cost goals and validate subsystem feasibility before transitioning into advanced/engineering development.

• A formal R&D program for area decontamination be established that will result in coordination of related programs and provide for phased development of a range clearance system, including mass munition disposal, to be operational by FY 80. The program should initiate immediate development of a recovery/ removal subsystem to be operational in FY 77.

SECTION II

PROBLEM ANALYSIS

A. PROBLEM DEFINITION

1. Scope. The exact magnitude of the decontamination problem has been difficult to determine because detailed information is not readily available. Preliminary investigation was accomplished through a review of open literature, military publications and correspondence; discussions with government agency representatives, including appropriate service personnel; and, visits to operational sites and R&D facilities. This investigation indicated:

a. the general nature of the problem is recognized by all the services; however,

b. there is no comprehensive DoD program to document the total acreage involved, the type and degree of contamination, physical characteristics of ranges and range usage data;

c. the criteria for range decontamination is not well defined; and

d. there is no formal R&D program which addresses the problem of mass area decontamination.

The Navy Ordnance Clearance Plan contains the most comprehensive assessment of the problem which exists to date.[1] Although the plan only addresses those range areas

[1]Commander, Naval Ordnance Systems Command, Ordnance Clearance Plan, 8 December 1972.

which are used exclusively by the Navy, the range survey information is representative of the conditions which exist on all military ranges. Because records of past usage of the majority of Naval ranges surveyed were not available, the ordnance to be anticipated and degree of contamination had to be estimated. Realistic estimates on the degree of subsurface contamination cannot be made without extensive records of range usage.

A major recommendation of the Navy Plan was that,

> a detailed survey of Navy target range areas be conducted as a first step in an ordnance clearance plan in order to determine accurately the actual areas which are in fact contaminated, the nature and extent of such contamination, and the pertinent characteristics of the areas in which the contamination exists.[2]

This recommendation is applicable to all service impact ranges.

Accurate range acreage figures are not available. The Navy study reported a total land area contamination of 757,227 acres, exclusive of the Marianas. Recent Army estimates of near-term range clearance requirements involve nine ranges for a total of 2,020,1?7 acres. Of this total, 2,007,121 acres are in Alaska where even surface clearance operations would be limited to the summer months. The Air Force has 7,867,000 acres committed to bombardment/gunnery range complexes. Some of this land is for administrative and base support functions; therefore, the actual acreage which has been subjected to contamination is not known.

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[2] Ibid.

2. Factors Bearing on the Problem. The principal factors that constitute (and complicate) the clearance problem can be summarized as follows:

- the aggregate acreage of the areas requiring clearance is very large and dispersed in isolated land and water regions throughout the world;
- many of the contaminated areas are saturated with practically every type of explosive ordnance which has been used by the military, including test and experimental items; some areas include both U.S. and foreign ordnance; ordnance casings are in varying states of damaged condition caused by impact and deterioration from long exposures; duds caused by fuze/firing train malfunction are numerous and difficult to identify; and, chemical changes of fillers due to soil element contamination can result in unstable residue. All of these factors complicate the clearance problem and impose serious hazards to personnel;
- specially trained and highly skilled personnel are required for clearance operations; current clearance techniques are slow and hazardous and available equipment was not designed for mass clearance;
- the process of detection, localization, identification and disposal of subsurface ordnance is extremely difficult and time-consuming; in circumstances wherein each item of ordnance

must be disposed of individually, the increased exposure times and the resultant hazards to personnel and equipment may not be acceptable;

- complete area clearance of subsurface ordnance, wherein penetration may exceed 40 feet in soft clay, is not practical using current equipment and techniques.

- present clearance techniques have an adverse impact on the environment which, in some locations, may not be acceptable to the local civilian populace nor in conformance with existing laws.

The scope and complexity of the clearance problem indicates an immediate need to identify critical capability gaps and design research and development programs which are responsive to both current and future operational requirements.

3. Responsibilities. The interservice responsibilities for explosive ordnance disposal are defined in the current joint service directive.[3] The directive defines explosive ordnance disposal as

> The detection, identification, field evaluation, rendering safe, recovery and final disposal of unexploded explosive ordnance (UXO). It may also include the rendering-safe and/or disposal of explosive ordnance (EO) which has become hazardous by damage or deterioration when the disposal of such EO requires techniques, procedures, or equipment which exceed the normal requirements for routine disposal.

[3] Department of the Army, Navy and Air Force, Interservice Responsibilities for Explosive Ordnance Disposal. OPNAVINST 8027.1E, AR 75-14, AFR 136-8, MCO 8027.1B, 25 September 1973.

Area responsibilities for each service include their respective installations and explosive ordnance in their physical possession or in assigned operating areas. Additionally, the Army is responsible for those land mass areas not specifically assigned to the other services.

General policies and procedures concerning disposition of ammunition, explosives, and other dangerous articles (AEDA) are contained in the Defense Disposal Manual.[4] Procedures for the disposal of real property, including decontamination actions, are set forth in DoD Regulations.[5] The substance of these regulations clearly indicates service responsibilities for ordnance disposal and area decontamination. They also substantiate the need to develop procedures and equipment for accomplishing these responsibilities.

B. IMPACT RANGE CHARACTERISTICS

1. Range Comparisons. It was initially intended that a review of range survey data would lead to a methodology for classifying impact ranges as a function of physical characteristics of each range and the penetration parameters of various types of ordnance. The resultant classification could prove valuable in developing gross estimates of the percentage of ordnance which would be found on the surface and at varying depths below the surface. To accomplish this classification, it would be necessary to interface the physical characteristics of the range against the dynamic and physical parameters of impacting ordnance.

As the work on this task progressed, it became apparent that the information which was available would not support this

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[4] Defense Disposal Manual, DoD 4160.21-M.

[5] Real Property Management, Disposal of Real Property, DoD Instruction 4165.12 of 23 July 1973.

type of approach. The gross descriptions of range soil composition as "sand and clay" or "topsoil" do not lend themselves to analysis of the penetration behavior of projectiles or to meaningful prediction of the percentages of various classes of ordnance that will occur at various depths.

As a result of the initial search for descriptive data on ranges, it was concluded that the Navy Clearance Plan contained the most comprehensive and recent data available. To make a meaningful comparison, that data which was applicable to the clearance problem was reduced to tabular form. A representative sampling of this information is shown in Table II-1. The objective of presenting the data in tabular form was to indicate commonalities, disclose informational gaps and identify the variable extremes of dispersed areas. The results were both revealing and disconcerting.

As would be expected for areas selected as target sites, the terrain can be generally categorized as flat or moderately hilly (rolling). The ground cover, when present, tends to be scrub brush and grassland. Extensive variation must be expected in the other physical characteristics of the ranges as well as the ordnance contamination.

It is apparent that no <u>general</u> ordnance clearance plan will suffice and that equipment and manpower needs must be addressed to the specific clearance task, based upon the characteristics of the particular impact area. Even when consideration is given to the known facts relative to an impact area, the clearance operational problems are accentuated by critical information gaps. Many established ranges are permeated with ordnance of unknown age, sensitivity and lethality. Records are insufficient or nonexistent. The type of ordnance and degree of contamination varies widely

TABLE II-1: Characteristics of Representative Impact Ranges.

ACCESS	SIZE	PHYSICAL DESCRIPTION						ORDNANCE CONTAMINATION				TERMINAL LAND USAGE	REMARKS
		Ground Cover	Terrain (Surface)	Soil Composition	Climate	Man-made Features	Other Features	Degree	Type(s)	Segmented Use	Time-frame Used		
NAVAL STATION, Adak, AK													
Mainland by vehicle, helicopter	34,340 Acres	Heavy grass;	Sloping to hilly	Rock, sand	Summer - cool, wet Winter - cold, wet	None	Marsh in Areas 3&4	Medium to heavy	Mines Artillery rounds Demolitions Bomb Dump	Area 1 Area 2 Area 3 Area 4	1940 (?) to Present	Unknown	Minimal environmental effects if cleared. Live ordnance.
NAVAL STATION, Kodiak, AK													
Mainland by vehicle, helicopter	227 Acres	Moderate timber	Hilly, rough	Loam, Fine sand and Rock	Summer - cool, wet Winter - cold, wet	Metal Structure	Disposal area	Very heavy	Bombs Rockets	None	1940 (?) to Present	To be transferred to the USCG	Minimal environmental effects if cleared Live - UXO
BOARDMAN TARGET RANGE, NAS, Whidbey Island, WA													
Mainland, by vehicle	46,000 Acres	Grass, Brush	Flat to Sloping	Topsoil	Summer - warm, humid Winter - cold, wet	None	Wind Erosion	Medium	Practice bombs; Rockets (inert)	None	1943 to Present	Industrial park; Nuclear power plant and farmland	Minimal environmental damage
Lake Hancock													
Boat	374 Acres	Grass	Flat; Thin strip of coastal beach	Sand	Summer - warm, humid Winter - cold, wet	None	Marsh strip	Light	Practice mines (inert)	None	1943 to Present	Industrial park; Nuclear power plant and farmland	Minimal environmental damage
Rosario Strait/Bird Rocks													
Boat or Helicopter	3 sq. mi. 1-mile radius	Barren	Rugged	Rock Formation	Summer - warm, humid Winter - cold, wet	None	Water depth - 300 feet	Light	Practice bombs; Rockets (inert)	None	Unknown	Unknown	Minimal environmental damage Some underwater contamination
Sea Lion Rock													
Boat	28 sq. mi. area; Land mass is 80 x 30 feet	Barren	Rugged	Rock Formation	Summer - warm, humid Winter - cold, wet	None	Rock is awash at high tide	Medium	Practice bombs; Rockets (inert)	None	1943 to present	Unknown	Minimal environmental damage Some underwater contamination
COMUSNAV, Philippine Islands													
Tabones Islet, Wild Horse Creek, Leon Creek - Area 1													
Boat	8,035 Acres	Brush	Hilly	Sand, rock	Tropical	None	None	Medium	Bombs, Naval rounds (L/ve)	Leon Creek	(?) to Present	Unknown	Light UXO contamination offshore.

TABLE II-1: cont'd.

ACCESS	SIZE	PHYSICAL DESCRIPTION						ORDNANCE CONTAMINATION				TERMINAL LAND USAGE	REMARKS
		Ground Cover	Terrain (Surface)	Soil Composition	Climate	Man-made Features	Other Features	Degree	Type(s)	Segmented Use	Time-frame Usage		
NAF, El Centro, CA — Chocolate Mountain Aerial Gunnery and Bombing Range													
Mainland by vehicle or helicopter	456,230 Acres	Barren	Rugged, Mountainous	Desert sand, thin soil crust	Summer - hot, dry Winter, warm, dry	None	None	Medium, to 12-ft depth	Bombs, 250 to 1000 lbs; Rockets; Mortars; Napalm igniters, fuses	None	1943 to Present	Unknown	Possible damage reports from residents of the Niland Area if detonations occur.
Target 68													
Mainland by vehicle or helicopter	1,599 Acres	Cleared of Vegetation	Rolling hills	Soil crust on sand	Summer - hot, dry Winter - warm, dry	None	None	Light to Medium to 12-foot depth	Inert ordnance: rockets, 20mm, bombs; Unignited flares	None	1953 to Present	Unknown	Range could only be surface cleared.
Target 95													
Mainland by vehicle or helicopter	640 Acres	Barren	Rolling hills	Desert pavement on clay soil	Summer - hot, dry Winter, warm, dry	None	None	Light to Medium to 12-foot depth	Inert ordnance: rockets, 20mm, bombs; Unignited flares	None	1952 to Present	Unknown	Range could only be surface cleared.
Target 103A													
Mainland by vehicle or helicopter	4,730 Acres	Sparse scrub brush	Flat	Desert pavement on clay soil	Summer - hot, dry Winter, warm, dry	None	None	Light to Medium to 12-foot depth	Inert ordnance: rockets, 20mm, bombs; Unignited flares	None	1952 to Present	Unknown	Range could only be surface cleared.
Carrizo Impact Area													
Mainland by vehicle or helicopter	640 Acres	Light scrub brush	Gentle Slopes to Rough Hills	Clay surface	Summer - hot, dry Winter - warm, dry	None	None	Unknown	Unknown	None	1952 to Present	Unknown	Range could only be surface cleared.
NAS, BARBERS POINT, Oahu, HI — Kahoolawe Island													
To Island by boat or helicopter	7,750 Acres	Grass, Trees	Hilly, deep ravines, steep cliffs	Silty clay, loam to 50 inches, soft igneous rock	Summer - warm to hot. Winter - warm.	None	None	Heavy, to 15 feet	All types, including 16-inch rounds (UXO)	None	1941 to Present	Suggested as site for nuclear power station	Rocks have high iron content. Unknown environmental effects if cleared.

TABLE II-1: cont'd.

ACCESS	SIZE	PHYSICAL DESCRIPTION						ORDNANCE CONTAMINATION				TERMINAL LAND USAGE	REMARKS
		Ground Cover	Terrain (Surface)	Soil Composition	Climate	Man-made Features	Other Features	Degree	Type(s)	Segmented Use	Time-frame Usage		
PACIFIC MISSILE RANGE, Point Mugu, CA													
San Nicolas Island													
To Island by boat or helicopter	3,200 Acres	Moderate to med. grass and brush cover	Rugged hills with high cliffs	Rock base with moderate earth crust	Summer - hot, humid Winter -	None	None	Heavy	20mm; 40mm; 4.5-inch barrage rockets	None	Pre WWII to Present	Unknown	Minimal environmental effects if cleared.
NO MAN'S 'SLAND, Cape Cod, MA													
To Island by boat or helicopter	6.28 Acres 1.(miles by 0.8 mi.	Grass & Brush	Gently undulating	Sandy glacial moraine	Summer - warm Winter - wet, cold	Shelters - for approx. 20 persons	Ponds & Marsh	Medium to Heavy, 8-foot depth	500-lb and practice bombs; ball ammo, rockets, flares. Emergency jettison.	West area South area	WWII to Present	Dept of Interior Wildlife Management Area; Recreational Land	Clearance operations would be hazardous to lobster and fish. Grass fires occur. Trenching would disrupt ecology.
NAVAL SHORE BOMBARDMENT RANGE, San Clemente Island, CA													
To Island by boat or helicopter	8,320 Acres	Grass & Brush	Some high cliffs	Rock and clay	Summer - hot, dry Winter - cool, wet	done	None	Heavy	Naval rounds - 20 mm to 16-inch (live)	None	1935 to Present	Unknown	Restoration may not be feasible. Large amount of UXO offshore.
CASTLE ROCK TARGET RANGE, San Clemente Island, CA													
To Island by hoat or helicopter	300-yard Radius	Barren	Small cliffs	Rock formations	Summer - hot, dry Winter - cool to warm	None	None	Unknown	MK76 Practice Bombs; Magnesium Photoflash shells	None	(?) to Present	Unknown	Minimal environmental effects if cleared.
ATLANTIC FLEET WEAPONS RANGE, P.R. (Eastern)													
Culebra Island													
To Island by boat or helicopter	320 Acres	Dense vegetation Elephant grass	Sloping to hilly	Volcanic rock, sandy shores, coral reefs	Summer - hot, humid Winter - cool to warm	None	None	Heavy	5-inch rounds MK 76, MK106 bombs; MK77 Fire bombs; Rockets	Naval Support Fire Air Impact Area	1942 to 1968 1968 to Present (inert)	Public Recreational Use	Clearance would destroy coral reefs. Light contamination offshore

TABLE II-1: cont'd.

ACCESS	SIZE	PHYSICAL DESCRIPTION						ORDNANCE CONTAMINATION				TERMINAL LAND USAGE	REMARKS
		Ground Cover	Terrain (Surface)	Soil Composition	Climate	Man-made Features	Other Features	Degree	Type(s)	Segmented Use	Time-frame usage		
At.Fl.W.Rng., cont'd													
Aqua Cay, Twin Rocks, Ladrone Cay													
By boat or helicopter	12.2 Acres	Barren Rock	Small hills	Rock formation	Summer - hot,humid Winter - cool to warm	None	None	Heavy	MK76,MK106 bombs; 2.75-inch rockets	None	1964 to 1971 (Inert)	Public Recreational Use	Clearance would destroy coral reefs. Light to medium contamination offshore.
Culebrita Island													
By boat or helicopter	290 Acres	Barren Rock	Rocky hills	Rock formation	Summer - hot,humid Winter - cool to warm	None	None	Medium	20 mm; 50 caliber, 30 caliber, Torpedoes	(Naro Point)	1948 to Present (Inert) 1948 to 1968 (Live)	Public Recreational Use	Clearance would destroy coral reefs. Light to medium contamination offshore.
Vieques Island													
By boat or helicopter	2000 Acres	Grass & Brush	Sloping hills	Clay over volcanic rock	Summer - hot,humid Winter - cool to warm	None	None	Heavy	6- to 16-inch; Up to 8-in.	Naval Artillery	1942 to Present (Live)	Public Recreational Use	Clearance would destroy coral reefs. Light to medium contamination offshore.
Fungy Bowl, Shark Cay, Palada Cays													
By boat or helicopter	35.7 Acres	Barren	Rocky hills heights to 180 feet	Rock formation	Summer - hot,humid Winter - cool to warm	None	None	Medium	2000-lb bombs	None	1942 to Present (Live)	Public Recreational Use	Clearance would destroy coral reefs. Light to medium contamination offshore.
POTOMAC RIVER RANGE, NWL, Dahlgren, VA													
Mainland, by vehicle or heli-copter	Land area - 1640 Acres Water - 45 sq.mi.	Scrub brush	Flat	Clay-loam, Marsh	Summer - hot,humid Winter - cold,wet	None	None	Light	Fused projectiles	Southeast river bank	1938 to Present	Expansion of Naval Facility for Public Use	Adjacent to naval Lab facilities. Clearance could cause damage to woodlands. This has first priority for decontamination under Naval Command.
								Light	Projectiles (UXO)	Southeast river bank	1918 to 1950		
								Heavy	Bombs (UXO)	East	1938-1944		
								Heavy	Grenades (UXO)	Far Southtip	1938-1946		
								Light	Bombs (UXO)	North Sec.	1938-1946		
								Heavy	Rockets (UXO)	N.E. bank	1944-1968		
								Light	Misc. (UXO)	River bank	1920-Pres.		

TABLE II-1: cont'd.

ACCESS	SIZE	PHYSICAL DESCRIPTION: Ground Cover	Terrain (Surface)	Soil Composition	Climate	Man-made Features	Other Features	ORDNANCE CONTAMINATION: Degree	Type(s)	Segmented Use	Time-frame Usage	TERMINAL LAND USAGE	REMARKS
NAD, Hawthorne, NV (Areas 1,2,3,4,5 and 6)													
Mainland by vehicle or helicopter	6,460 Acres	Moderate brush	Sloping to hilly (foothills)	Alluvial clay	Summer - hot, dry Winter - warm, dry	Barracks (Area 6)	None	Light	MK 93 fuses with boosters	Area 1	Unknown	Unknown	Some offshore contamination (Area 4) - 3-inch and 5-inch rockets.
								Medium	5-inch rounds, 100-lb bombs 2.75-inch rockets, fuses, grenades, 220-lb frag. bombs	Area 2			
								Light	Fuses	Area 3			
								Light	3.5-inch rockets	Area 5			
PINECASTLE TARGET, NAS, Jacksonville, FL													
Mainland, by vehicle or helicopter	5,025 Acres	Wooded, pine trees	Flat	Sand, Gravel, Clay	Summer - hot, humid; Winter - cool, wet	None	Swamp surrounding Lake George	Light	30 caliber	Naval Area	1951 to Present	To improve National Forest	Concern shown for forest area. Fires have caused over 7000 acres of timber loss. Scattered flares, practice bombs and rockets offshore.
								Medium	500 lb bombs, MK82 GP, 750 lb. M117; Zuni 5-inch rockets; 2.75-inch rockets (live).				
									500-lb bombs and misc.	Air Force Area	Unknown; Inactive since 1951		
									Flares, Practice bombs, Rockets	Lake George	Unknown		

among the established impact ranges. The situation is further complicated by the fact that very few ranges have been segmented to establish control of the type of ordnance impacting in a specific area. It is not unusual to find live and inert ordnance, cluster bomblets and pyrotechnics, rockets and projectiles all in the same area.

Discussions with Air Force and Army EOD personnel indicate these conditions are typical of most ranges. The Hill AFB range complex has been partially segmented at the request of EOD personnel to facilitate continual range clearance operations.

2. Ordnance Penetration Parameters. The most unpredictable factor in planning for range clearance operations involves the estimative process for determining the extent of subsurface contamination. The many variables which affect ordnance penetration cannot be generalized or reduced to simple tabular form. Analytical studies of penetration depths would place all bombs, and most projectiles somewhere below the surface.[6] A separate analysis of penetration depths which confirms this prediction was made by study investigators.[7] These conditions are not borne out, however, by operator recollection, personal observations by study investigators, or range survey reports including photographs of range surface contamination. The high incidence of impacted ordnance that actually exists on the surface seems to contradict the analytical predictions of penetration.

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[6] Appendix A., Part II, Non-nuclear Warhead Terminal Ballistic Handbook and Joint Service EODB 60A-1-1-2, 21 December 1964.

[7] See Appendix I, Estimation of Projectile Penetration Depths, this report.

This does not belie the theoretical analyses that have been made; it does indicate that there are factors impinging on the behavior of the penetrating ordnance that require consideration.

The predictions based upon theoretical analysis need to be compared with the results of carefully controlled impact tests, where projectiles or bombs are delivered under firmly established delivery conditions and impact an area of the test range where soil conditions and parameters have been carefully measured. One facet of the theoretical analysis that tends to be arbitrary is the description of the soil penetrated by the ordnance. It is conceded that there are instances of 30-foot and greater penetrations. It is probable that this occurs when the penetration path is through a consistently loose or very loose, plastic soil. More often, however, the soil profile will tend to show stratification that increases in density or hardness with depth. A more accurate prediction of the penetration depth must take this soil stratification into account; the impediment can be significant, explaining the high occurrence of ordnance on or very near the surface.

Once statistical data has been derived on penetration and offset characteristics, it may be possible to design a relatively simple slide rule calculator that would give realistic predictions. This device would be a useful tool for the range clearance supervisor as well as for the planners.

For the purpose of this study, an effort was made to place analytical boundaries on the depths to which varying percentages of ordnance would be found on a typical range. Because of the paucity of empirical data it was necessary

to derive the percentage figures from information contained in range survey reports, photographic comparisons, actual site inspection and discussions with U.S. and U.K. EOD personnel. Table II-2 categorizes the results. The percentages contained in the table are used in this study as being representative of typical range contamination depths. Although the percentages appear to have some empirical validity, they are not critical to subsequent analyses or study conclusions.

TABLE II-2: Occurrence of Impacted Ordnance.

DEPTH	PERCENT OF TOTAL
Surface	50%
to 1-1/2 ft.	30%
to 3 ft.	15%
to 6 ft.	3%
to 25 ft.	<2%
over 25 ft.	<1%

C. CLEARANCE OPERATIONS

Range clearance operations involve a series of sequential and systematic actions that are closely interrelated. The Joint Service EODBs (Explosive Ordnance Disposal Bulletin) describe the essential elements of a surface clearance operation and set forth the requisite safety precautions. Appropriate procedures have been developed by the various services at the EOD unit level.[8]

[8]For example, 2701st EOD Regulation 55-2, Range Decontamination Procedures, 7 January 1974.

Analysis of the sequential procedures of a typical range operation is a prerequisite to determining the relative utility and feasibility of employing major equipment.

1. Area Survey. The area survey is essential to proper planning for any range clearance operation. The survey must incorporate a review of range records and history with actual reconnaissance to determine:

- Range Characteristics
- Type and Degree of Contamination
- Type of Clearance Required
- Personnel, Materiel and Support Requirements.

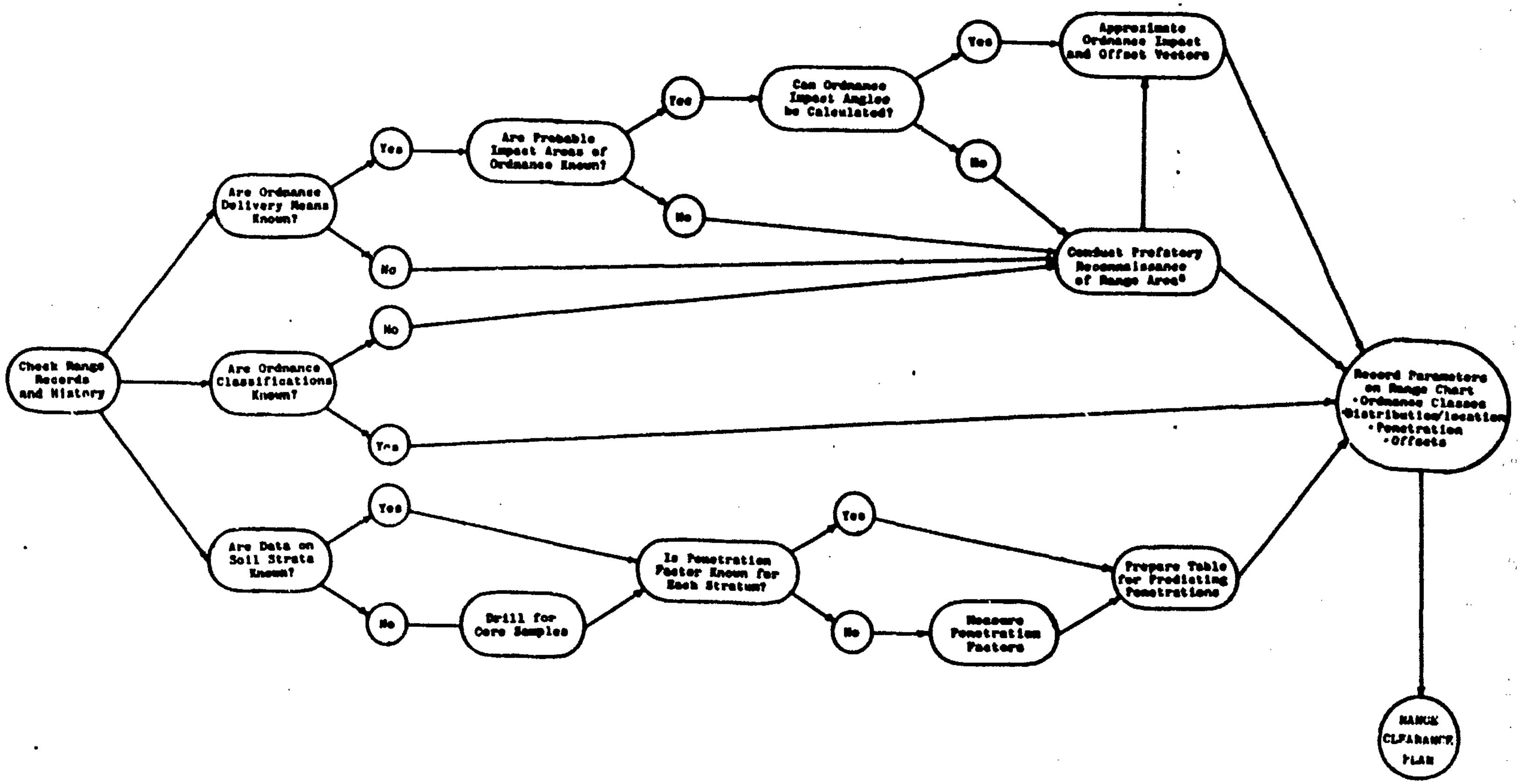
Figure II-1 illustrates the relationships and sequence of actions involved in the area survey. As shown in the Figure II-1, three questions are immediately posed.

a. Are the means of ordnance delivery known?

If the range history is sufficiently accommodating, data should be tabulated so that a useful categorization can be made regarding:

- air-dropped ordnance
- air-to-surface rockets/missiles/gunnery
- surface-to-surface rockets/missiles
- artillery and Howitzer rounds
- mortar rounds
- other

Further definition to the answer of this question would examine any segmentation of the impact range regarding these categories of delivery means (e.g., bombing zone as opposed to artillery zone). Somewhat congruous to this is the ascertaining of the generalized ordnance impact angle, and germane to this is the



*May be integral with the "Preparation Phase" of the range clearance operation.

FIGURE II-1: Determination of Impact Range Ordnance Parameters.

resolution of high or medium altitude bombing vs. low altitude bombing, high trajectory vs. low trajectory artillery fire, etc.

b. Are the ordnance classifications known?

The ordnance class may be no more definitive than that, say, 1000-lb and 500-lb bombs have impacted on the range. The classification could be extended to reveal, "1000-lb, general-purpose bomb" or, "500-lb, low-drag H.E. bomb." Review of historical records and on-site inspection must be conducted to provide the data input for evaluation of the removal problem, particularly with regard to the probable condition of impacted ordnance and the hazards presented to the personnel and equipment engaged in the removal operations. Some degree of ordnance classification is required to allow for reliable estimates as to penetration depths.

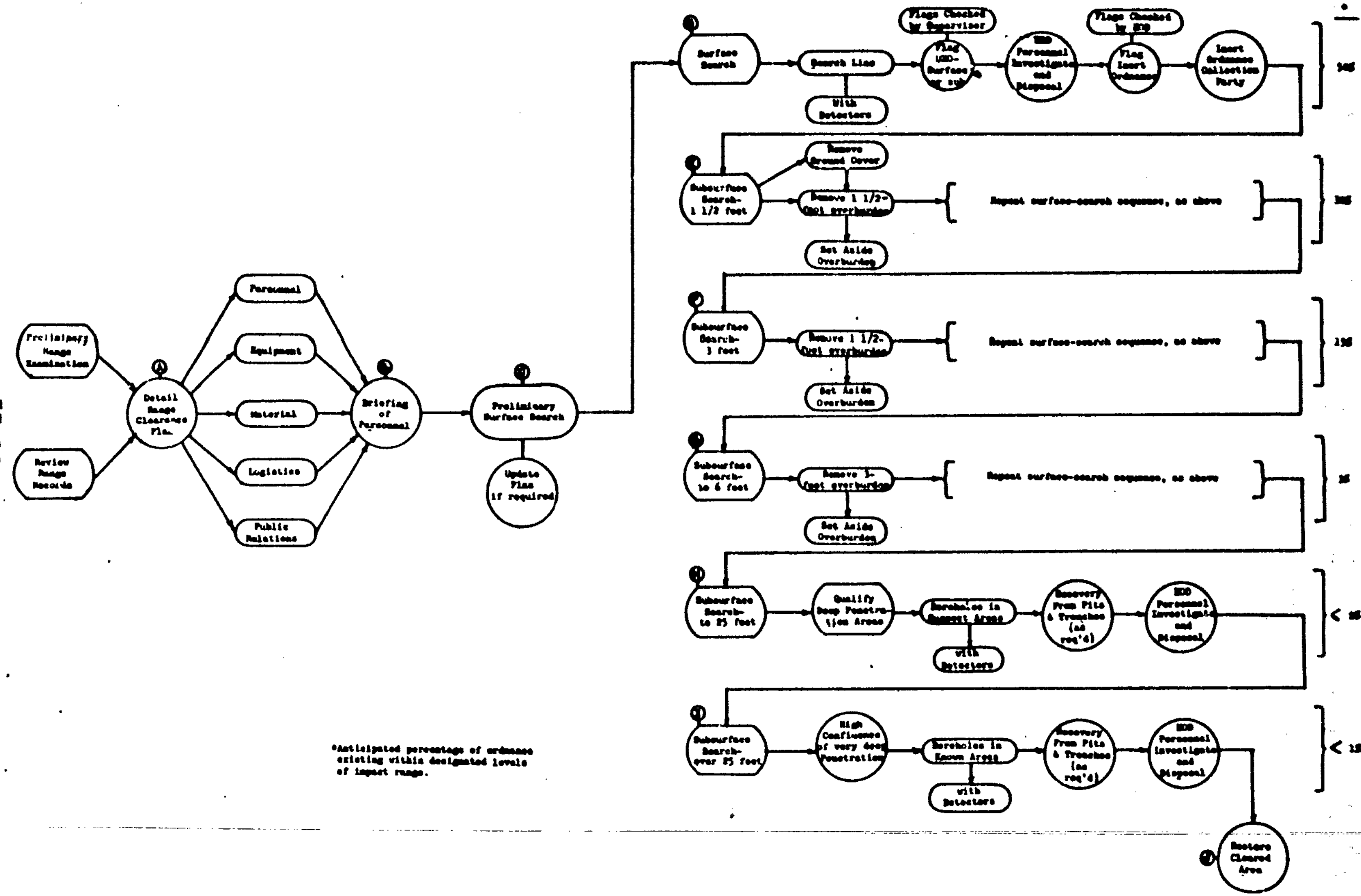
c. Are data on the soil strata known?

The occurrence of impacted ordnance at various depths is subject to the variations dictated by the ordnance characteristics and parameters of the soil strata. Core samples of the substrata should be obtained by drilling into areas of the impact range that are representative of the geological profile. Penetration factors can than be determined from the core samples of each stratum (and of the surface) so that ordnance penetration can be predicted. These factors are discussed in more detail in Section II. B. and in Annex A, Estimation of Projectile Penetration Depths.

In addressing these three questions, some reliance has been placed upon the availability of range records or an accounting of the history of ordnance impact in the range area. The existence, or even the extent, of this information does not supplant the necessity of conducting a prefatory reconnaissance of the range area. Such a reconnaissance is necessary to establish requirements for manpower, equipment, logistic support, etc. This point becomes of escalating importance as the subsurface clearance problem increases in magnitude.

2. Clearance Sequence and Procedures. Once a determination has been made as to the need for subsurface clearance, ordnance penetration depths become the key factor in planning. As previously discussed, the ordnance penetration data analysis provides predictive penetration depths that are not always consistent with range survey reports or the observations of experienced EOD personnel. Consequently, the depth/percentile figures contained in Table II-2 were used herein to provide realistic parameters for sequencing the subsurface clearance operation.

The range clearance sequence outlined by Figure II-2 encompasses those actions required for both surface and subsurface clearance. As shown in the figure, the detailed range clearance plan is based upon the total inputs from the review of range records and from the preliminary range examination. Once the requirements have been derived from the plan, actions can be initiated for acquiring the requisite personnel, equipment, material, and establishing a logistics net. The preliminary surface search serves the two-fold purpose of allowing supervisors to modify the search



*Anticipated percentage of ordnance existing within designated levels of impact range.

FIGURE II-2: Range Clearance Sequence.

procedures as required and to add "first-hand" information to background data affecting the conduction of the total clearance operation.

Steps "D" through "J" in Figure II-2 comprise the total range clearance operation. Whether or not all these steps need be exercised depends upon the range clearance plan requirements and continual reassessment of the situation as the clearance operation progresses.

The steps comprising the surface search sequence "D" are consistent with those currently employed by Joint Service EOD units. The use of detectors in this phase is dependent on the extent of surface contamination. In cases where surface contamination is extensive the initial sweep would mark suspected EO and remove ferrous debris. A follow-up search with detector personnel would be required to flag suspected subsurface ordnance. As discussed in later sections, heavy equipment can also be employed to accomplish surface clearance.

The subsurface clearance phase begins with the sequence shown at "E". The selection of search/excavation increments of 1-1/2 feet was based on the following factors:

- depth/percentile figures contained in Table II-2;
- overburden removal effectiveness of candidate excavation equipment;
- effective ranges of current ordnance detection equipment.

Although the excavation concept is unique to clearance operations, under appropriate circumstances the advantages appear to be threefold:

(1) excavation enhances subsequent detection of buried ordnance by reducing the range factor;

(2) it ensures a high probability of total clearance; and,

(3) if contamination is extensive it may prove to be faster and more economical.

Removal and processing of the overburden for ordnance can be accomplished several ways as discussed in Section II-D. For example, the equipment design should provide flexibility and allow for selective performance functions; i.e., stripping, rooting, scraping, sifting, excavation, loading, etc. The procedures for handling overburden would be selected as functions of range configuration, capability of excavating/hauling equipment, desired clearance depths and land restoration requirements. For a typical operation using a dragline type excavator and the sequence in Figure II-2, a "Lane Stripping" concept could be employed. In brief, the area to be cleared would be divided into lanes; as the dragline progresses the overburden is dumped adjacent to the lane. When the first lane is cleared to the desired depth, the overburden is processed and dozed back into the cleared area. Lanes can be staggered and working parties placed at diagonal ends of the clearance area to provide safe separation distances in the event of accidental detonation.

The excavation depth is a direct function of the amount of ordnance remaining subsequent to each cut. As shown in Figure II-2 this is determined by the detection team. If the detection team survey corroborates estimates that 95% of the ordnance was within three feet of the surface, then boreholing and selective excavation may prove more cost-effective

for recovery of the remaining ordnance. Decision factors would be derived from cost trade-offs and intended future usage of the range area.

3. Land Restoration. Land restoration is a major consideration when excavation techniques are used for clearance. The extent of restoration will depend on terminal land usage subsequent to the clearance operation. Step "J" in the search sequence, Figure II-2, indicates restoration as the final phase; this does not preclude use of techniques such as "Lane Stripping" to accomplish partial restoration as the operation progresses. As a minimal requirement, backfilling of holes and trenches would normally be required. The re-contouring of the surface, proper replacement of topsoil, and reseeding or planting of trees, shrubs or bushes will be dictated by local reclamation statutes as well as planned terminal land usage. Appendix II summarizes the laws that govern lands in public domain and under state jurisdiction. Reclamation requirements must be included at the genesis of the planning so that the restoration can be handled in the most cost-effective manner.

4. Selection Criteria for Clearance Methods. The selection of clearance methods for mass decontamination is dependent primarily upon the physical characteristics of the range and the degree of contamination. There are several basic questions that must be addressed in the clearance plan. The answers to these questions can provide the initial criteria for selection of the most effective method(s) for decontamination.

a. Size of clearance area and distribution of ordnance within the area:

- is a large percentage of the ordnance large, medium or small?
-

- is it clustered or dispersed, shallow or deep?
- what is estimated maximum and mean penetration depth?

b. Ordnance classification and probability of accidental detonation:

- what types of ordnance have impacted on the range?
- what is the condition of the dud ordnance?
- what is the probability of detonation?
- do those items which are likely to detonate contain sufficient high explosive to cause irreparable damage to equipment?

c. The physical nature of the area that impacts on clearance operations:

- must ground cover (e.g., trees, bushes, high grass or reeds) be removed? If overburden must be removed, is it stone/rock, friable material, earth, sand, clay, marsh, etc.?

d. The character and significance of geological features:

- are there water-bearing formations with resulting water disposal problems?
- are there fractures, faults, shear zones and drastic soil consistency changes?

e. Climatic considerations:

- are there anticipated climatic conditions which may render certain equipment inoperable during unfavorable seasons?

f. The life and expected production rate of the clearance operation:

- is the operation expected to be continuous or intermittent?

- how many hours constitute a working day and how many working days are in a week?

g. The calculated volume of overburden and hauling distance to each disposal site:

- what is the range acreage and to what depth should it be cleared?
- how far does each category of recovered ordnance have to be transported?
- how far does stripped overburden have to be transported?

The equipment performance characteristics contained in Section II-D and Appendix IV can be compared with the above criteria to provide a basis for equipment selection.

5. Range Data Collection. The need for accurate information on the extent and type of contamination of the various military ranges cannot be overemphasized. This need has been confirmed by review of the raw data available to the Navy study, discussions with various service representatives and analysis of records maintained by local range management offices. Those records which do exist do not contain adequate information to factually determine the amount and types of ordnance expended on a given range. This has been further complicated by the administrative regulations of the individual services for record disposal. The Air Force has recognized this problem and has a suggestion under consideration which was initiated by members of the 2701st EOD Squadron at Hill AFB.[9] In summary, the suggestion provides for the establishment of a range contamination computer data bank and reporting system. Evaluation of the suggestion by the

[9]Suggestion Number 00-74-1323, Establishment of Range Contamination Reporting Procedures, 8 January 1974.

Headquarters Command at Hill AFB concurred with both the need for establishing range contamination reporting and with the rationale provided in the suggestion. It was noted that the suggestion clearly outlined the requirement, but did not provide a method for its accomplishment. Although it is not within the scope of this study to analyze the data system collection requirements or develop a methodology, there are several factors which must be considered.

The data base would begin with the more static physical characteristics of the range area. Primary among these would be:

a. Dimensions of Total Range Area
   (1) Dimensions of Segmented Areas (if any)
   (2) Elevations
   (3) Depressions
   (4) Water Depth (where applicable)

b. Seasonal Climate Descriptions

c. Terrain Description

d. Tide and Water Current Data (if applicable)

e. Ground Cover

f. Underwater Visibility (if applicable)

g. Soil Composition (soil profiles must be known to 35 feet or to rockbed, enough profiles must be recorded to be representative of all areas of the range.)

h. Man-made or Other Special Features on the Range

The system must permit easy insertion of the characteristics of impacting ordnance. Fundamental data would include:

a. Type of Ordnance

b. Cumulative Contamination of Each Ordnance Type (in each area of the range)

c. Probable Condition of Each Piece of Ordnance

(1) detonated on impact

(2) live (UXO)

(3) inert

(4) practice-marker charge

(5) practice-dummy

(6) unknown

d. Date and Time of Ordnance Delivery

e. Ordnance Delivery Means

(1) trajectory

(2) drop altitude

(3) speed, direction and location of delivery platform

f. Weather Conditions Concurrent with Ordnance Delivery

(1) rainfall

(2) drought

(3) freeze

(4) thaw

The range data collection system should allow for the dynamic character of range utilization. Programming must provide for continuous updating to include records of decontamination operations. The management of impact ordnance ranges, and subsequent ordnance decontamination, would be enhanced considerably by the systematic recording of events and the application of inter-related data to provide predictive location of impacted ordnance.

D. SURVEY OF EARTH-MOVING EQUIPMENT

1. General Descriptions. The machinery and equipment used for surface mining, strip mining, and construction work have been designed to excavate and haul prodigious amounts of material and to perform over extended periods of time. A survey of the capabilities of this equipment was conducted to determine those performance features which are applicable to range clearance.

There are two major divisions to be made when discussing the classifications of mining and construction equipment:

a. Excavators-
   - Shovels
   - Draglines
   - Scrapers and Rippers
   - Bucket-Wheel
   - Dredges
   - Hydraulicking

b. Haulage-
   - Dozers
   - Trucks
   - Scrapers
   - Conveyors

The variation in size and cost of this equipment covers a wide spectrum. Shovels can be small, such as the tractor-loader backhoe, or as large as a stripping shovel with a 180 cubic yard dipper capacity. Draglines in common usage range in bucket size from 7 to 85 cubic yards. The most popular size range for scrapers is between 18 and 26 cubic yards (loose material capacity). With improved

technology, the trend is in the direction of greater capacities. Bucket-Wheel Excavators (BWEs) are highly specialized machines and are almost always built to specification for a particular application. BWEs, on a continuous operation, can out-perform shovels and draglines as long as the overburden material is not hardbed. BWEs have been designed to give 1000 to 11,450 loose cubic yard capacities. Dredges come into consideration where the clearance operation must be performed along shorelines or on tidal land. Some dredges can be dismantled for relatively easy transportation to new sites. Hydraulicking techniques, using high-pressure waterjets, could have a very special application in clearance areas where other excavating equipment is inoperable. The mucky, swampland environment often associated with tropical regions lends itself to excavation by hydraulicking as does, conversely, frozen ground and tundra.

Haulage capacity of bulldozers varies with the shape and size of the blade and with the weight of the material moved. A representative dozer with a modified "U" blade has a blade capacity of 7 to 9 cubic yards. Trucks, often considered as the conventional haulers, run the gamut from small to large (60 to 110-ton range) tonnage. Trucks applicable to massive clearance operations are configured as "rear-dumps" (conventional), "rear-dump rockers" (tractor-trailer), "side-dumps" (tractor-trailer), and "bottom-dumps" (tractor-semitrailer). Tractor scrapers are usually used for removal of overburden but are also popular tools in hauling operations because they can dig their own loads, transport the loads at speeds of 20 to 35 mph, and effectively spread the loads in the dumping area, thus substantially reducing supplementary dozer-spreading requirements. A careful analysis of the haulage requirements at some

impact ranges may indicate application for conveyor belt systems. The attributes of conveyors could be attractive where vehicular traffic is to be kept to a minimum during massive clearance and where the time period of the clearance operation justifies the engineering costs.

The advantages and disadvantages of each class of excavating and hauling equipment are presented in Appendix IV. Although they all would offer some contribution in massive range clearance, several classes of equipment display unique operational capabilities which should be closely examined.

Draglines offer significant "reach" and are adaptable to diverse terrain conditions. The ability to work above or below grade is a noteworthy example of these features. The dragline rig also presents a configuration that would facilitate modification for performance of range clearance tasks. This latter issue is explored further in Section II-D-5, Innovations in Equipment Usage.

Conveyor belt systems would be of prohibitive expense in some clearance tasks but may be worthy of consideration in long-term, large-area operations. Once installed. conveyor systems could supplant trucks for haulage of both overburden material and removal of ordnance material.

2. Military Development of Earth-moving and Construction Equipment. The military inventory includes equipment which are applicable to the massive area clearance problem. Some are already in use for range clearances, such as the D-7 and D-8 Tractors (see Figure II-3) and the earth-moving Scraper shown in Figure II-4.

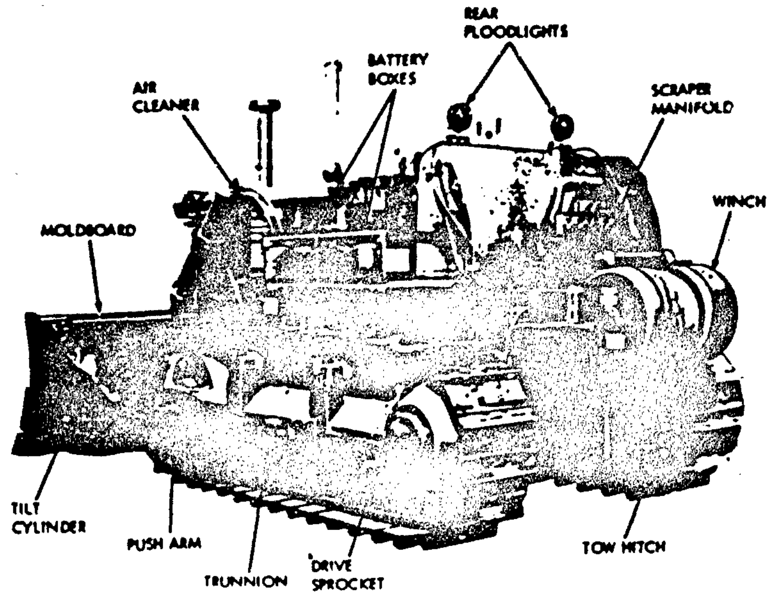


FIGURE II-3: Medium Tractor, D-7.

The D-7, Medium Tractor can be used as the prime mover for a scraper and ripper and can be provided with a root blade for additional ripping and clearing of the overburden. The 18 cubic yard scraper has a heaped capacity of 25 cubic yards for hauling and its 120-inch blade can dig to 15 inches.

Consideration should be given to equipment in the military inventory which could be adapted to use in range clearance. A decided advantage would be that the equipment is already hardened and offers some protection to the operator. This equipment includes the M88, Medium Recovery Vehicle; the M-113, Armored Personnel Carrier; the M578, Recovery Vehicle; the M728, Combat Engineer Vehicle; and the 20-ton Rough Terrain Crane, which is air-transportable.

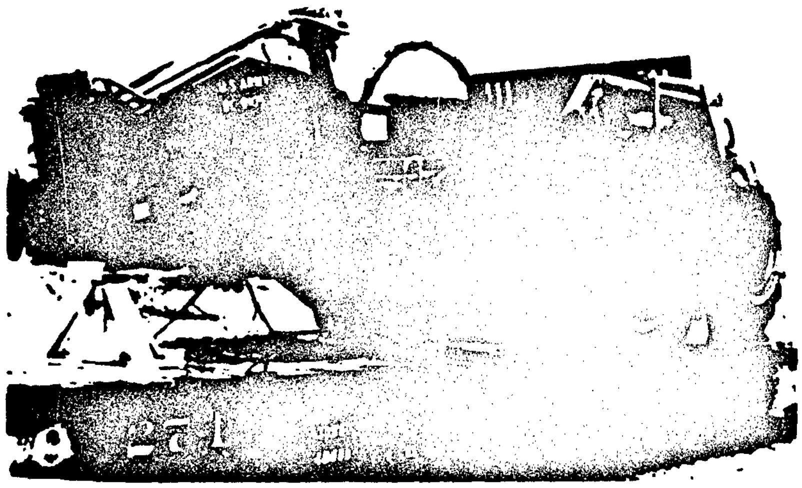


FIGURE II-4: Scraper, 18 Cubic Yard.

The M88 (Figure II-5) was designed to perform the functions of battlefield rescue and recovery of disabled medium tanks and comparable-size equipment. Its 25-ton hoist winch capacity and 45-ton tow winch capacity suggest that only moderate modification would be required to employ the M88 for ordnance recovery and disposal on an impact range. Mounting a dozer blade on this vehicle would provide the capability to remove 18 inches of overburden during the subsurface search phases of clearance.

The Armored Personnel Carrier, M-113A1 (Figure II-6) is a light, full-tracked armored carrier designed for continuous cross-country operation. The M-113/M113A1 version can cross inland waterways and also serve as a cargo carrier and transport behicle for litter patients. Additionally, the basic vehicle design with a modified superstructure may

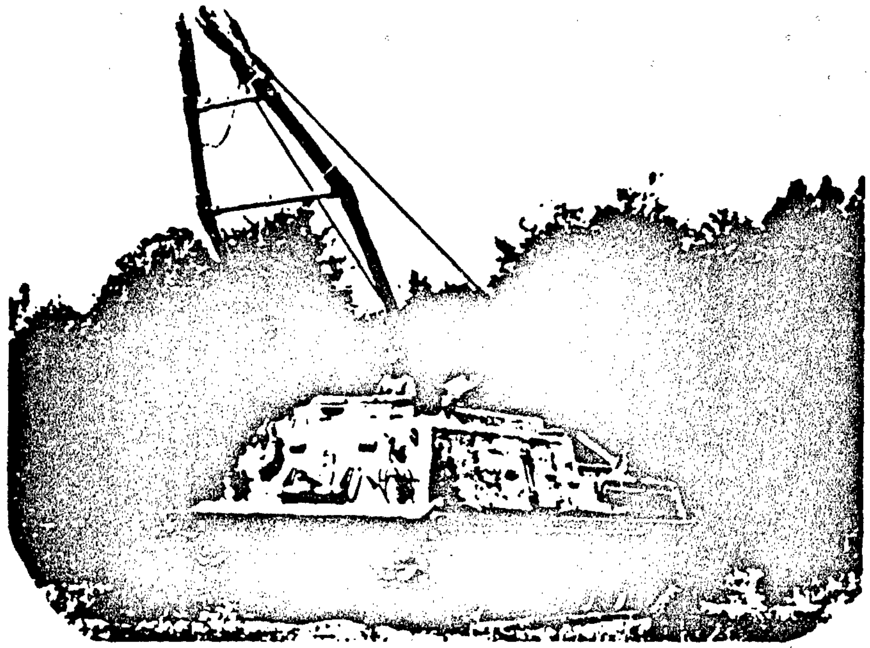


FIGURE II-5: Medium Recovery Vehicle, M88.

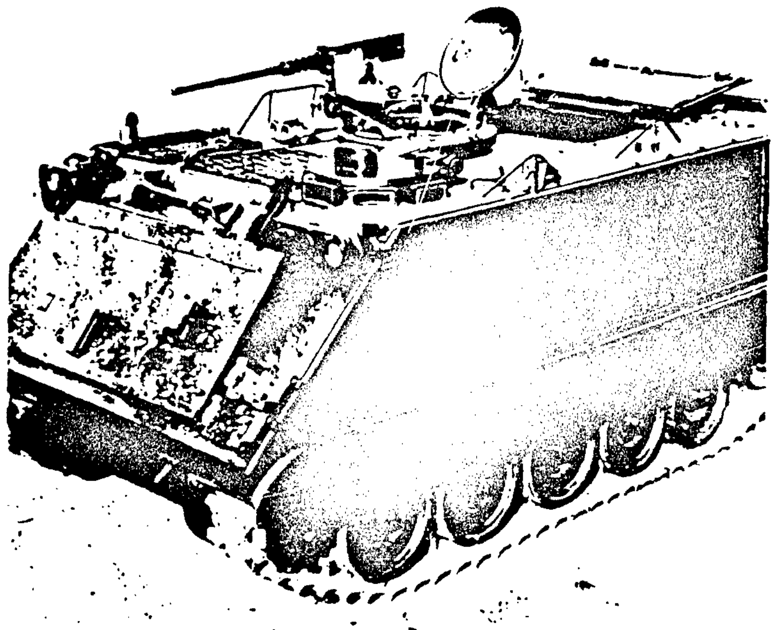


FIGURE II-6: Armored Personnel Carrier, M-113.

be used as a mobile command post, a fire direction center and a communications center. This vehicle could serve the roles of personnel transport, commo center and sensor platform in clearance operations. Some tests were recently conducted at Picatinny Arsenal using a modified M-113 as the prime mover for a rock-picker.

The M578 Recovery Vehicle, shown in Figure II-7 is used for maintenance support of tactical and combat vehicles. It is air-transportable and is designed to service, repair and tow vehicles weighing up to 30 tons. The hoist capacity is 15 tons. It is lightly armored but would afford protection to personnel engaged in peripheral range clearance tasks.

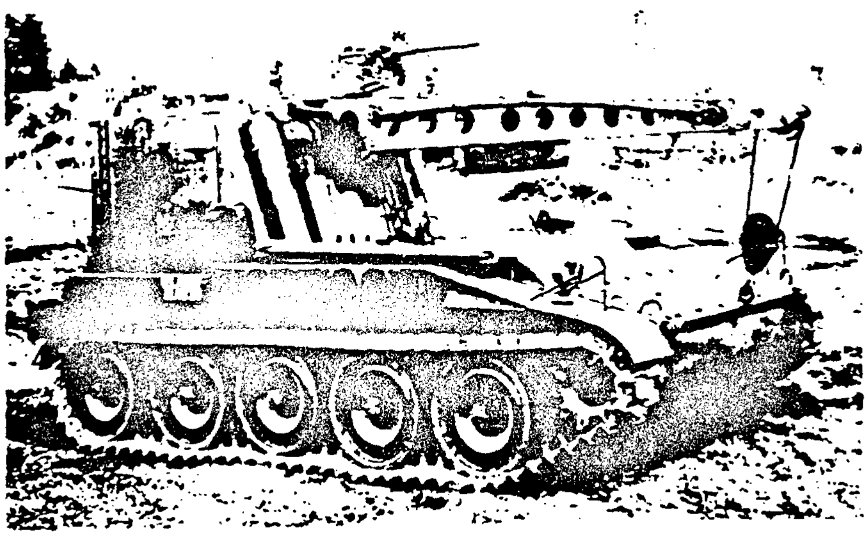


FIGURE II-7: Recovery Vehicle, M578.

The M728 (Figure II-8) was designed to perform pioneer tasks (construction/demolition) in support of combat operations. Its "A" frame boom has a 17,500-pound lifting capacity and the dozer blade can be used for a cutting depth of six inches. This vehicle is heavily armored and, with appropriate precautions, could be used to expose shallowly-buried ordnance. The vehicle has a two-speed tow winch with a pulling capacity of 25,000 pounds.

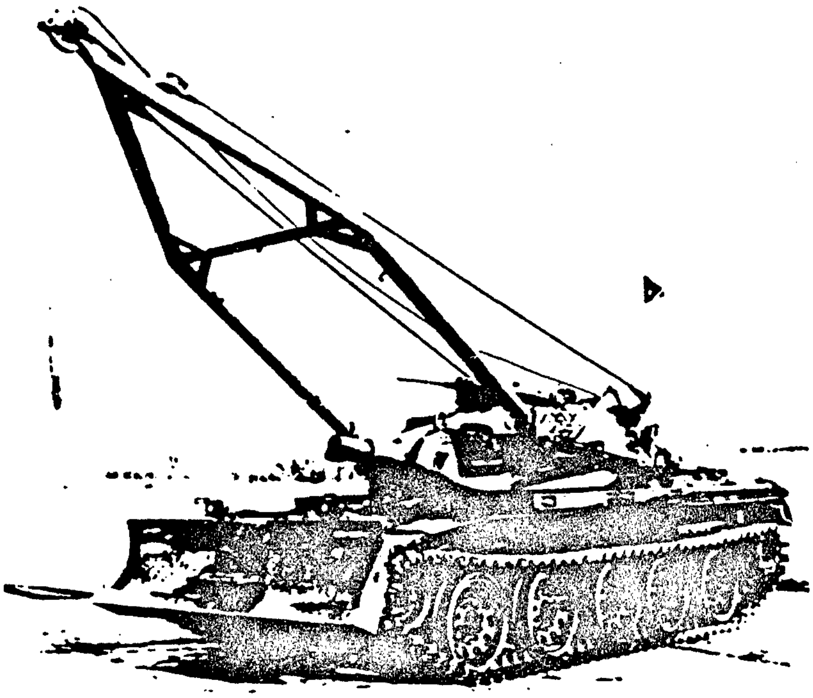


FIGURE II-8: Combat Engineer Vehicle, M728.

The 20-ton Rough Terrain Crane was specifically developed for dragline and clamshell operations, limited

bulldozing, bridge assembly and pile driving. The crane, shown in Figure II-9, has a lifting capacity of 40,000 pounds.

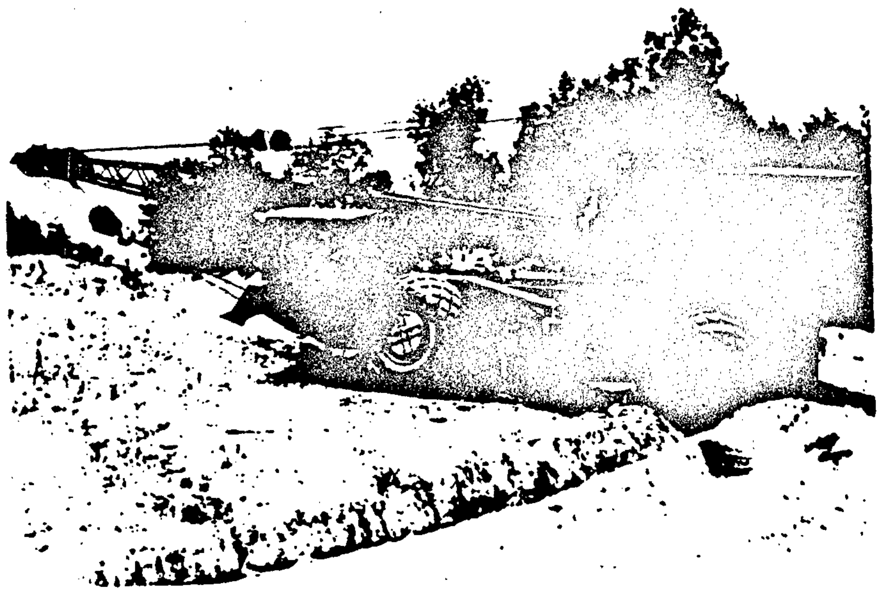


FIGURE II-9: Rough Terrain Crane, 20-Ton, Air Transportable.

These vehicles serve as examples of on-line equipment which could be used in massive range clearance operation with only minor modification.

The U.S. Army has embarked on an R&D program to develop a new Family of Engineering Construction Equipment (FAMECE). This system will fulfill varied requirements for construction missions in the 1980 to 1990 time-frame. The

system concept centers around the use of a standard, high-density, proved power module to supply the power to a family of work modules. The FAMECE concept is illustrated in Figure II-10.

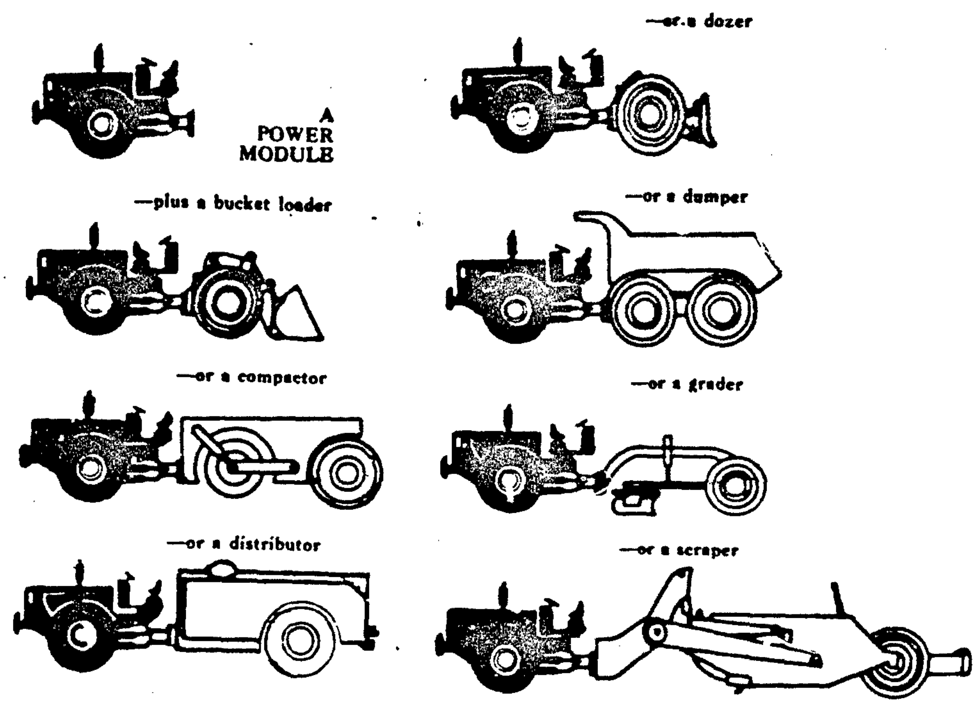


FIGURE II-10: Family of Military Engineer Construction Equipment - FAMECE.

Each construction vehicle, which is the combination of the power module with a work module, will have a high production capacity and will be capable of performing as well or better than the item it is intended to replace in the Army inventory.

The FAMECE is aimed at reducing the logistics burden complicated by the numerous makes and models of military and commercial equipment now used in the Army. It is a design goal that all the modules in this new family of construction equipment will be dimensioned so that they can be transported and parachute-delivered by U.S. Air Force aircraft (C-130E, C-141, and C-5A) and that each module will be capable of being airlifted as a separate external load on the medium-lift helicopter, CH-47C.

Two contractors have developed very different designs for this concept. The Clark Equipment Company power module and scraper module are shown in Figure II-11 and II-12.

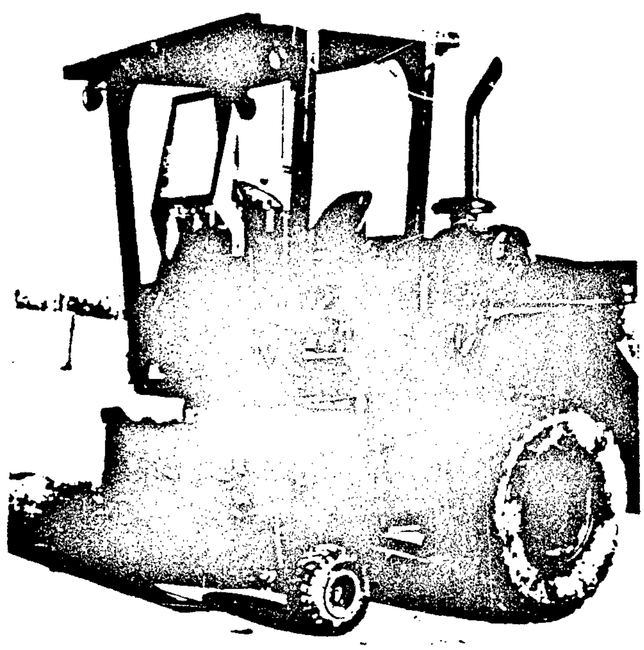


FIGURE II-11: Power Module - Clark.

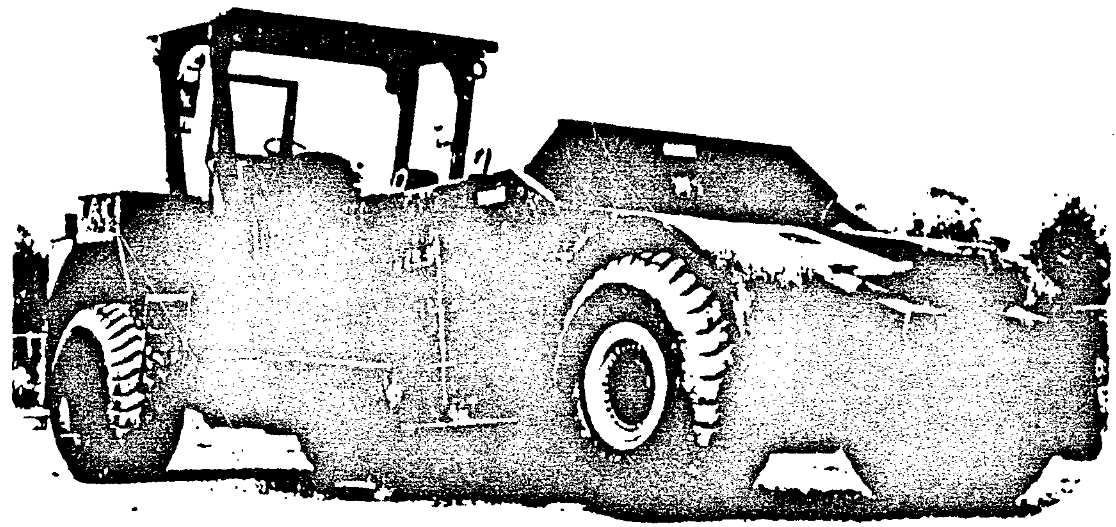


FIGURE II-12: Scraper Module - Clark.

The Lockheed Missiles and Space Company power module and scraper module are shown in Figures II-13 and II-14.

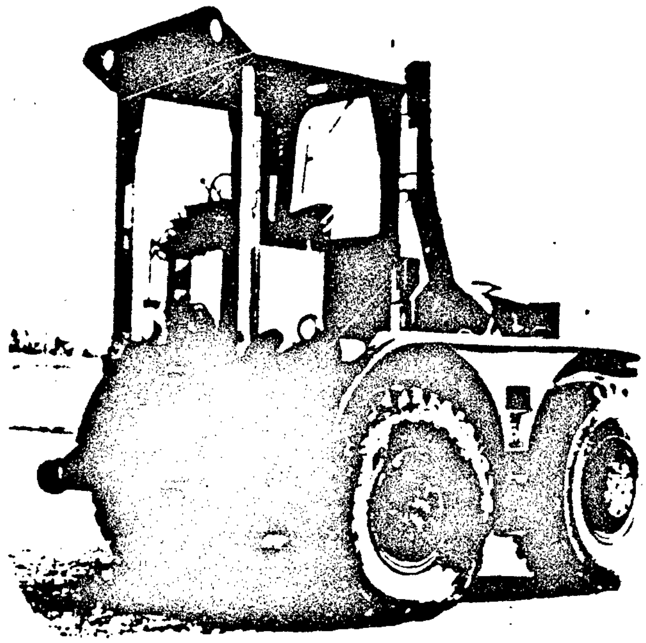


FIGURE II-13: Power Module - Lockheed.

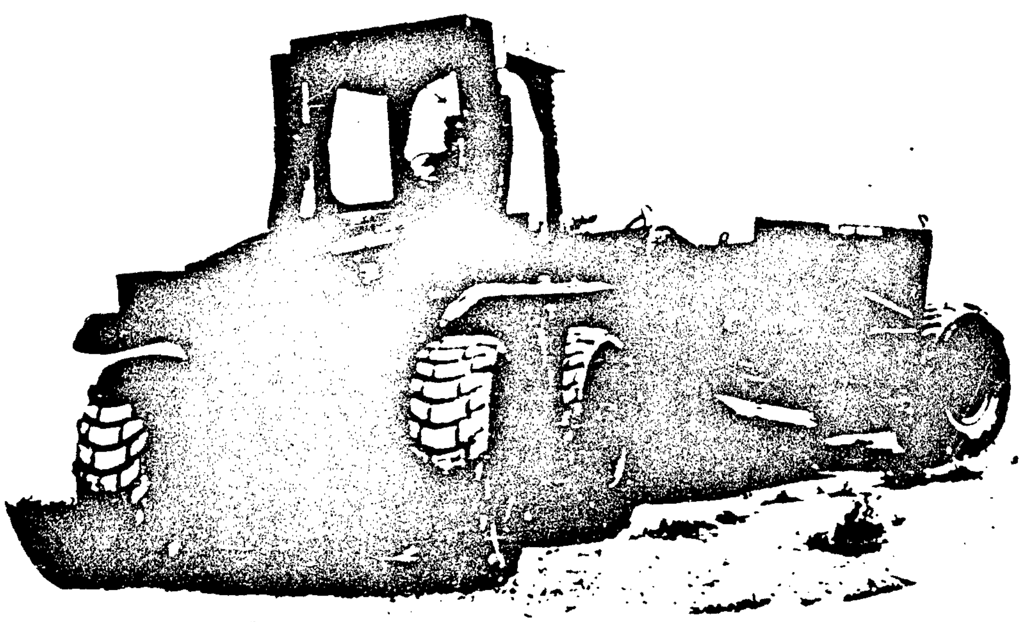


FIGURE II-14: Scraper Module - Lockheed.

3. Other Equipment Sources. Equipment developed for other industrial or military functions should continually be evaluated for potential application to clearance problems. A rock-picker (Figure II-15) produced for clearing rocks from tillable fields, may be employed in the surface-clearance phase of ordnance decontamination if the ordnance items on the surface are not too large. A magnetic "sweeper," developed for clearing runways of metal objects, may also be useful in the surface search phase of range clearance. Both of these pieces of equipment are currently under investigation for use in ordnance clearance by Picatinny Arsenal.

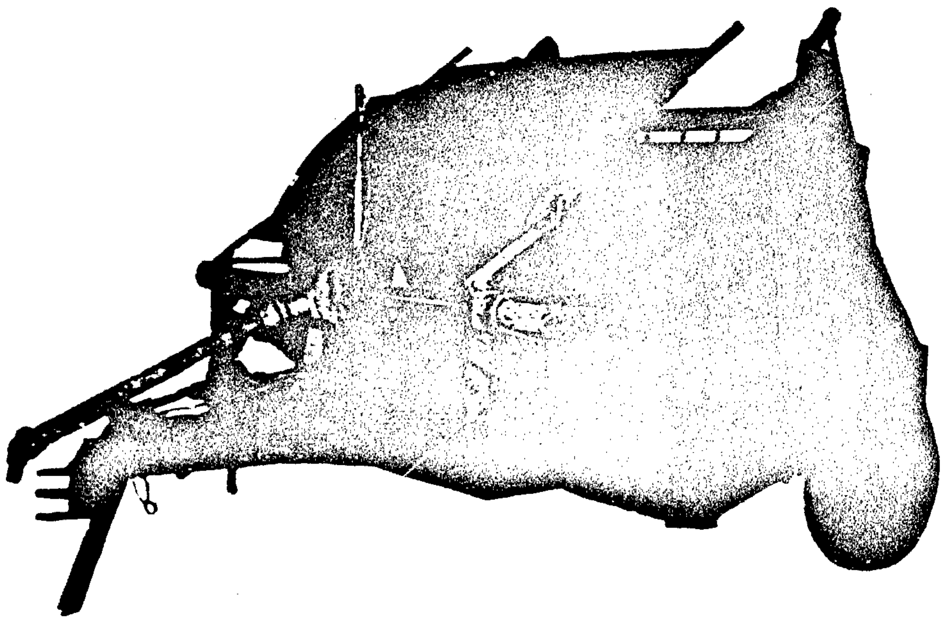


FIGURE II-15: Anderson Rock Picker.

An interesting vehicular concept is being developed under NASA direction. The design criteria for a lunar "rover" vehicle parallel those that might be considered for a range reconnaissance and utility vehicle. Highly maneuverable, extremely lightweight and able to negotiate severe terrain, a vehicle such as the ELMS (Figure II-16) would provide valuable mobility and could perform a number of utility functions in the clearance activity.

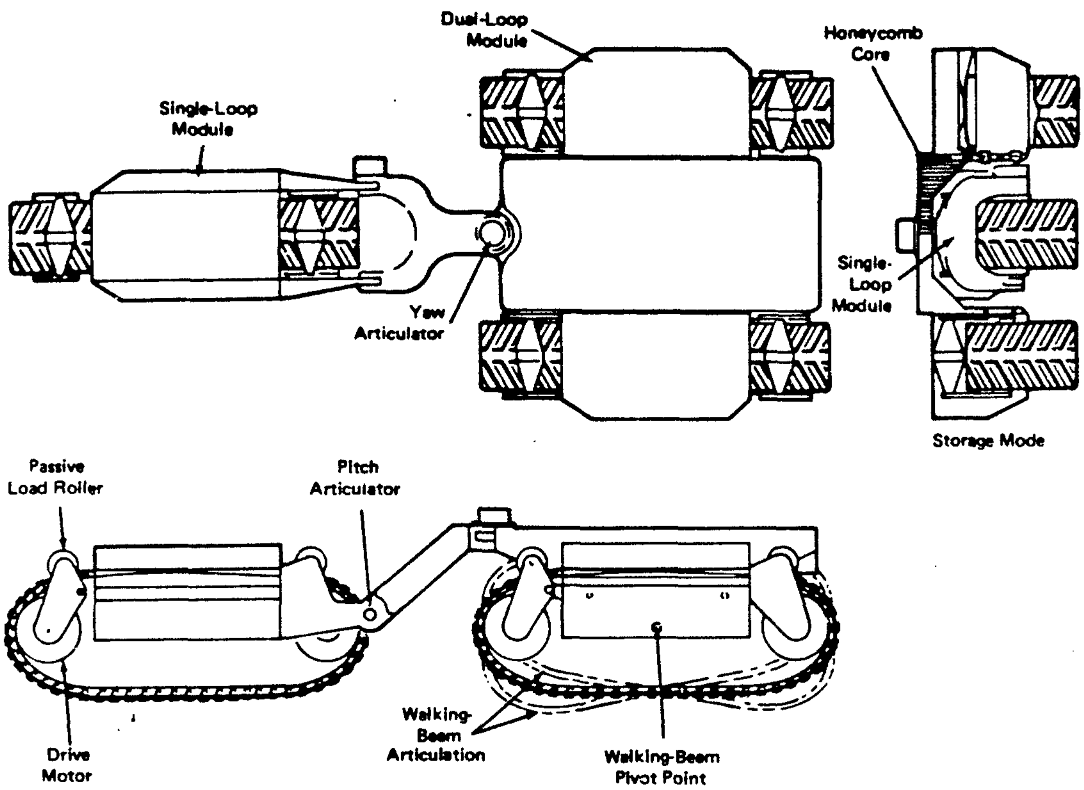


FIGURE II-16: Basic Layout of Three-Loop Articulated ELMS Roving Vehicle with Internal Electric Drive.

4. Cost and Time Analysis. The acquisition costs of major construction and surface mining equipment are extremely high. To include the full range of these costs (purchase, freight, assembly, taxes, etc.) would be extraneous to this analysis. Current commercial equipment is overly complex and sophisticated for the tasks to be performed in support of range clearance. It is envisioned that the unique capabilities of mine machinery which are applicable to range clearance can be embodied in a simplified design. Accordingly, government acquisition costs would be lower; it is also conceivable that certain equipment might be contracted for or leased for a specific operation.

In order to present a cost perspective, on-site operation and maintenance costs have been calculated for representative equipment. Cost and time data for area excavation have also been developed to allow for comparison with alternative methods of clearance. The Maplin Sands cost/time comparison with a typical dragline is presented merely as an analogy and is not intended to be used as a cost-effectiveness analysis.

The following examples demonstrate how the cost data contained in the tables was calculated:

Model 120B Dragline

Fuel	$10.00/hr
Oil, Grease, etc.	3.33/hr
Operator(s)	12.30/hr
Maintenance (Parts & Labor)	7.53/hr
Total	$33.16/hr

Since,

bucket capacity = 5 cu. yds

and

operation cycle time = 28 sec.

then, Production Rate $= \frac{(5 \text{ cu yds})(3600 \text{ sec/hr})}{28 \text{ sec}}$

$= 642.85$ cu yds/hr;

and,

Unit Cost $= \frac{\$33.16/\text{hr}}{642.85 \text{ cu yds/hr}}$

$= \$0.052/$ cu yd.

Typical 22 Cubic Yard Scraper

Fuel	$10.00/hr
Oil, Grease, etc.	.79/hr
Operator	4.25/hr
Maintenance (Parts & Labor)	3.00/hr
Tires	1.89/hr
Total	$19.93/hr

Since,

Ave. Capacity = 22 cu yds

and,

Ave round trip = 2400 ft @ 18 mph

then, Production Rate $= \frac{(22 \text{ cu yds})(5{,}280 \text{ ft/mi})(18\text{mph})}{2400 \text{ ft}}$

$= 871.2$ cu yds/hr;

and,

Unit Cost $= \frac{\$19.93/\text{hr}}{871.2 \text{ cu yds/hr}}$

$= \$0.0228/$cu yd

The unit cost per cubic yard of excavation for representative equipment is shown in Table II-3. As a basis for comparison, the costs and operation time for typical draglines, a scraper and a BWE to excavate one acre (medium digging) are shown in Table II-4. Cost comparison curves for excavating and hauling are contained in Figures II-17 and 18.

It would be most informative if the cost and rate of clearance using current techniques could be compared with a specific system involving excavating equipment. As has been noted previously, the only validated subsurface clearance rate data was gathered at Maplin Sands, U.K. Discounting the many obvious yet unresolved variables, it is interesting to make a

Table II-3: Excavating Equipment Cost Breakdown

Equipment	Fuel Costs \$/hr	Oil & Grease \$/hr	Operator \$/hr	Parts Labor \$/hr	Total \$/hr	Capacity Per Hour yd^3	Capacity Per Cycle yd^3	Cycle Time sec.	Unit Costs \$/yd^3
Dragline 15 cu yd	10.00	2.50	12.30	38.59	63.39	744	15	58	0.085
Dragline 5 cu yd	10.00	3.33	12.30	7.53	33.16	642	5	28	0.05
Scraper	10.00	1.95	4.25	3.00	19.93	871.2	22	420[1]	0.02
BWE	2.32	----	22.69	73.73	98.34	9000	25	----	0.011

1. Cycle time includes round trip of 2400 feet to dump.

Table II-4: Costs To Excavate One Acre To Varying Depths

Depth to be Cleared (yds)	Amount to be Cleared (cu. yds)	Excavation Costs and Times			
		Dragline 15 cu yd	Dragline 5 cu yd	Scraper[1]	BWE
Surface[2] 0.0	4820 sq yd (1 acre, surface only)	$72.90 @ 1.15 hrs	$52.72 @ 1.59 hrs	$20.93 @ 1.05 hrs	N/A
0.5	2410	$204.85 @ 3.04 hrs	$163.88 @ 3.7 hrs	$233.27 @ 12 hrs	$26.51 @ 0.267 hrs
1.0	4820	$409.70 @ 6.08 hrs	$327.76 @ 7.4 hrs	$467.54 @ 24.3 hrs	$53.02 @ 0.535 hrs
1.5	7230	$617.00 @ 9.12 hrs	$491.64 @ 11.2 hrs	$701.31 @ 36.50 hrs	$79.53 @ 0.803 hrs
2.0	7640	$819.00 @ 12.00 hrs	$655.52 @ 14.9 hrs	$935.08 @ 48.6 hrs	$106.64 @ 1.071 hrs
5.0	24,100	$2123.45 @ 35.58 hrs	$1691.52 @ 38.76 hrs	$2358.13 @ 122.45 hrs	$265.10 @ 2.676 hrs

1. Cycle time includes travel distance of an average of 2400-foot round trip
2. Costs for surface drag are based on a $/hr basis, not $/yd

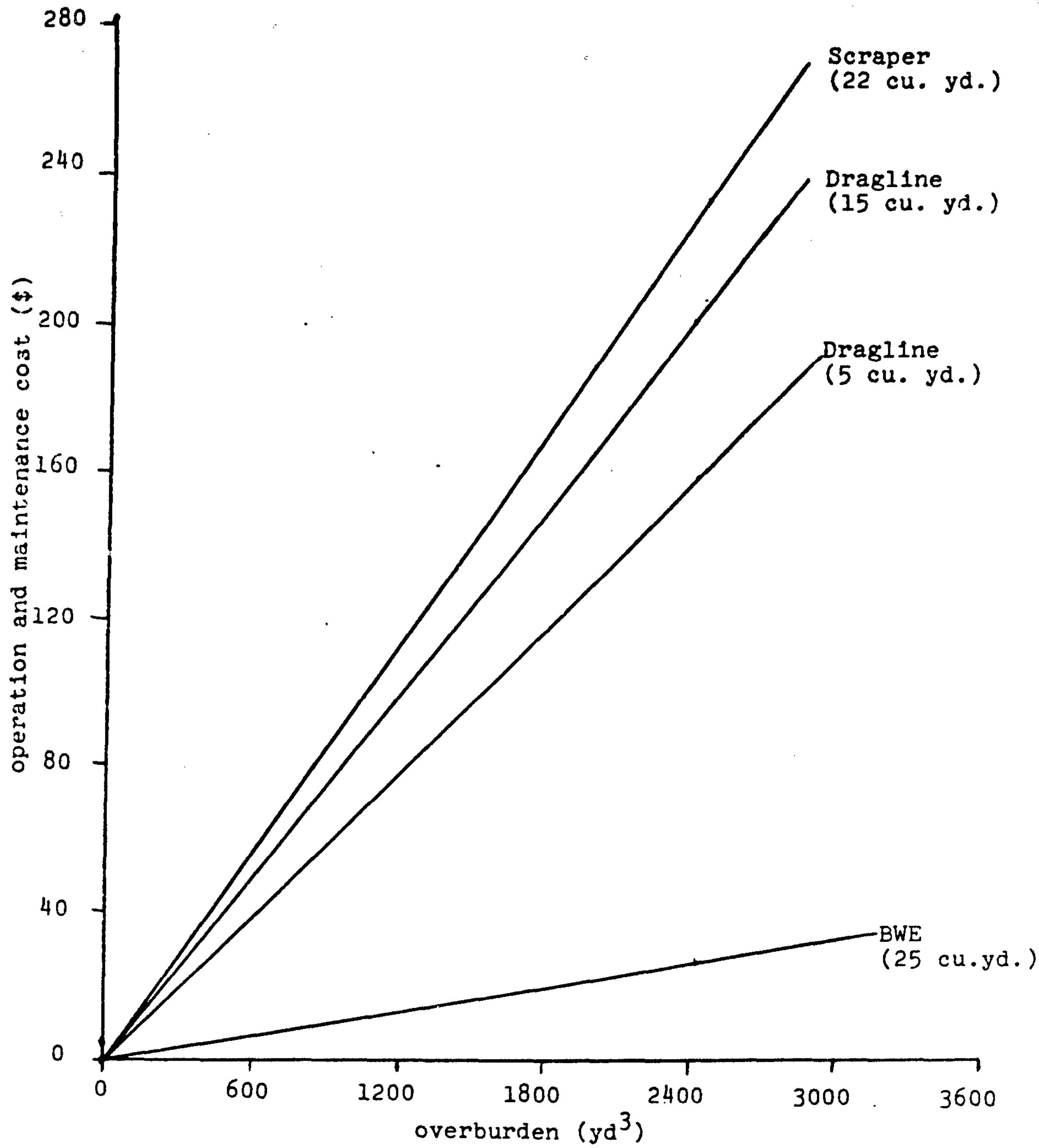


FIGURE II-17: Excavating Costs

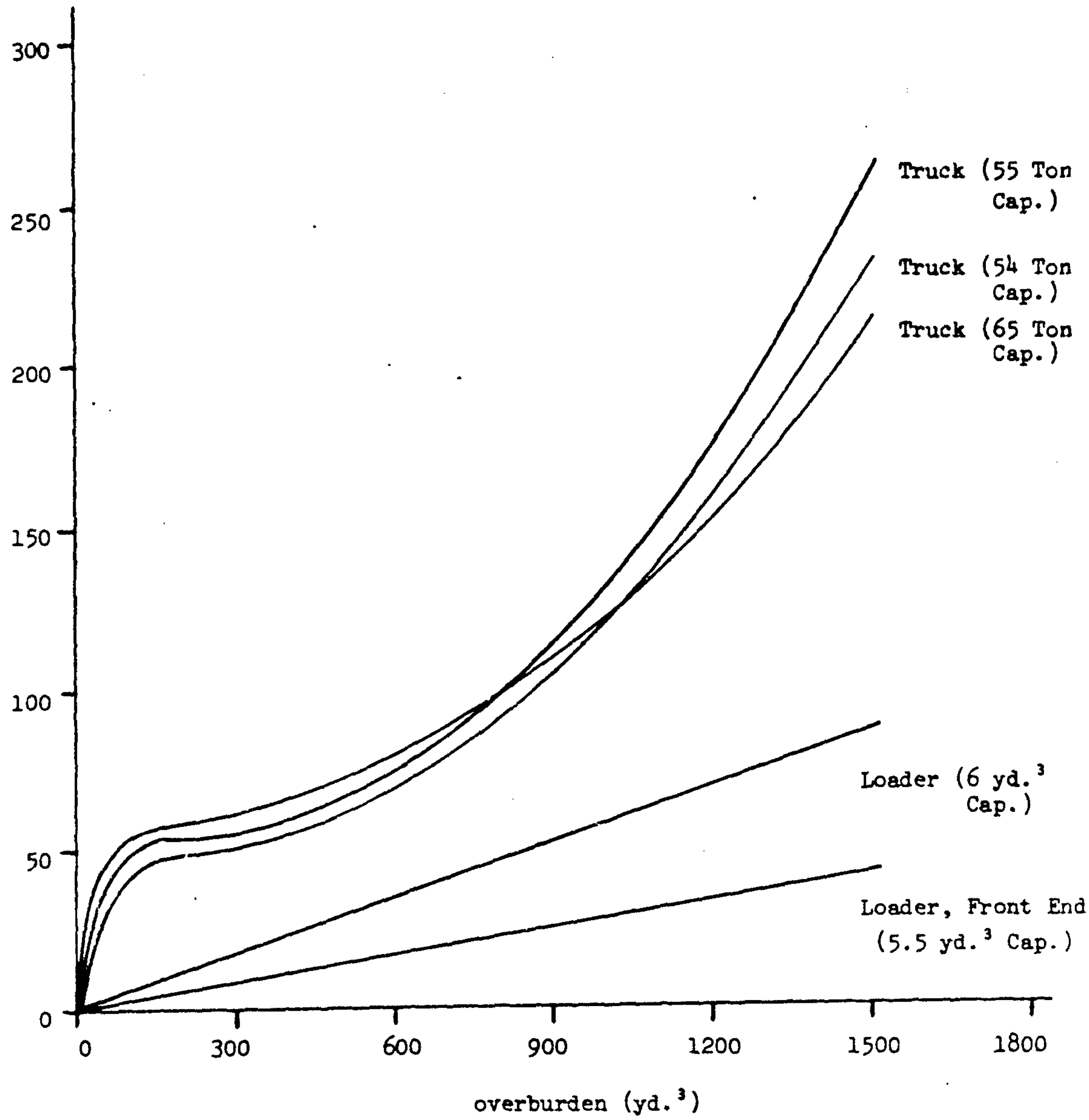


FIGURE II-18: Hauling Costs.

simple comparison of an analogous situation using excavating equipment.

The techniques employed at Maplin Sands are described in detail in Appendix V. The clearance rates were calculated from data gathered over an 18-month period. They are shown in Table II-5 for a clearance down to a depth of 4.5 feet.

Table II-5: Clearance Rates At Maplin Sands, U.K. (approx. 4.5-foot depth)

Personnel	Time Basis	Rate
200	7-day week	19.8 acres/week
200	50 weeks	988 acres/year
10	5-hour day	0.101 acres/day
10	8-hour day	0.162 acres/day

The dragline technique would involve removal of overburden in 1.5-foot increments to allow for ordnance recovery as the operation progresses. This technique is discussed in Section II-C-2. Removal rates for an unmodified dragline are contained in Table II-4. From Table II-5 it can be seen that 10 men can clear an area of 0.162 acres in an 8-hour day to a depth of 4.5 feet. Extrapolating from the clearance rates in Table II-4, it can be shown that an unmodified dragline with a capacity of 15 cubic yards can excavate 0.877 acres to a depth of 4.5 feet in an 8-hour day. It would require 54 men to clear an equivalent area in the same time frame.

To carry the analogy one step further, the operating costs were pro-rated for a man- and a machine-day. Assuming an E-5 pay grade average for clearance personnel ($33.73 per day, excluding per diem), it would cost approximately $1822.00 per 8-hour work day to clear the dragline equivalent of 0.877 acres. Operating costs for the dragline to excavate the same acreage in 8 hours would be $541.00, or an operating cost reduction of approximately 70 percent. As previously noted, the dragline

costs do not include amortization of the acquisition cost.

5. Innovations in Equipment Usage.

a. Protection. Safety of personnel is a paramount consideration in any ordnance disposal operation. Because of the high acquisition costs of major equipment that may be used for clearance operations, provisions must be made for minimizing equipment damage in the event of accidental detonation. The protection problem will require further study and analysis; a few alternatives are presented below for future consideration. Protection for both the operator(s) and the equipment might be accomplished as follows:

(1) Armor Plate- "hardening" the operator position on the equipment so that it will withstand shock and shrapnel effects. This would include flak suits and steel helmets worn by equipment operators.

(2) Protective Revetments- equipment performance on station for a majority of the operational time can be shielded from the probable ordnance location by a revetment; the obstruction must be of the proper size that it will shield the operator from direct blast effects but will not unduly restrict the equipment functions. A dozer can be used to build a revetment between the work area and the equipment, allowing enough clearance for the booms and cables to function but protecting the operator cab from blast effects and shrapnel. Even with the revetment in place, some parts of the equipment are exposed to damage, should a detonation occur. Also, the operator cannot watch the dragline bucket during the positioning, drag and fill phases of the operation cycle.

(3) Grade Difference- where possible, the equipment may work from a higher or lower grade (elevation) so that the operator position is always protected by surface contour.

(4) Remote Operation- this places almost the entire emphasis on the safety of the operator and very little on the equipment.

(5) Hardening the Main Chassis, or Structure, of the Equipment- if the equipment is normally operated from one location in the clearance operation, emphasis can be placed on the hardening of only those portions of the structure which are exposed; if the equipment is mobile in its clearance function, modification must focus on armor protection. Investigation of previous armor material research, such as the development of composite armor for riverine warfare craft in Southeast Asia, may lead to innovative measures for protection that do not entail major restructuring.

(6) Protecting Booms, Cables and Buckets- in assessing equipment survivability, these components are the most vulnerable. They can be viewed from two standpoints: as expendable components in a low-probability detonation area; or, as worthy of special protection in a high-probability detonation area. Booms and cables can be afforded some protection from shrapnel by providing them with protective sleeves or "Vee" channels, as shown in Figure II-19. which will tend to deflect the metal and rock dispersed by a detonation.

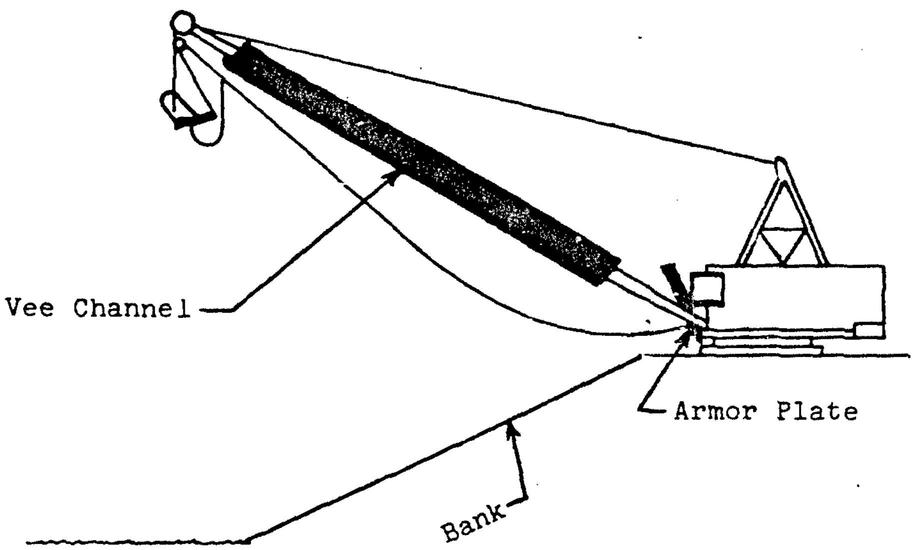


Figure II-19: Vee Channel and Armor Plate Protection

The added weight, particularly when applied to lever arms, may require additional structural supports and the upgrading of cables. Buckets can be considered as either expendable or in need of hardening, depending upon the detonation hazards anticipated in the operation.

b. Remote Control. Ultimate protection of the operator results when he can be physically removed from the operations area and can control the equipment from a safe position. Complete remote control of the equipment to be used for clearance operations (i.e., positioning the operator at a safe standoff distance from the equipment) would be the most desirable but imposes obvious cost and technological burdens. A reasonable compromise would consist of relocating the operator station to a less hazardous position on the equipment and, in that sense, remoting the equipment operation.

A remote TV monitor for the operator may be one approach to the viewing problem; positioning an observor off to one side (in a bunker), with radio communications to the dragline operator, would be another.

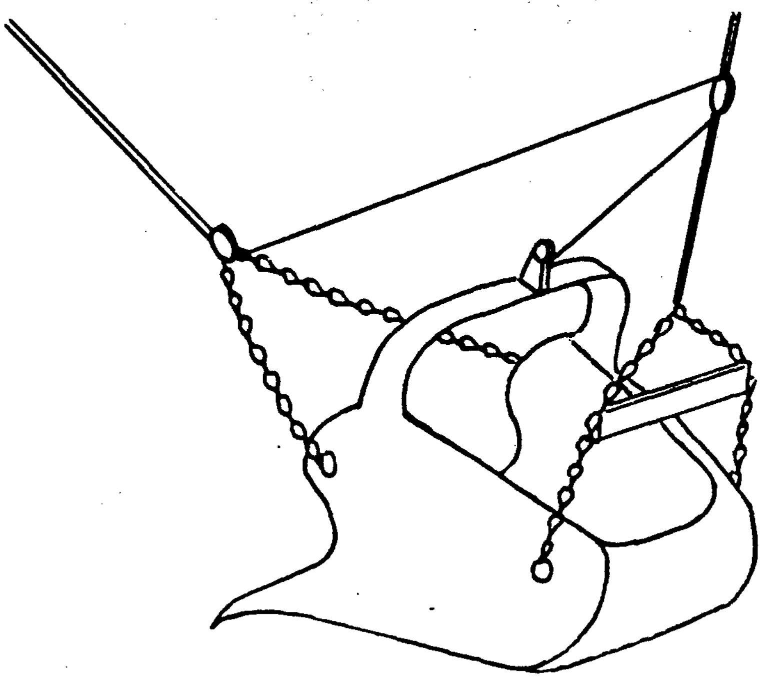
c. Bucket Modifications. Consideration has been given to modification of the dragline bucket. There are two obvious approaches. One would be to harden the bucket so as to increase its survivability; this may be the proper course of action if probable detonations will be of low order, or if the blast effects do not exceed those of antipersonnel mines and grenades. Another approach would be to consider the bucket as expendable and to fabricate the bucket from material sufficiently strong enough for the dragging and hoisting operation, but where its loss from a detonation would not be prohibitively expensive. Detonations have occurred in dragline buckets during surface mining operations. In an interview with a strip mine equipment operator. several instances were related where the bucket was in direct contact with previously-placed blasting charges (approximately 250-lb charges) when they detonated. In

a few cases, the buckets were cracked by the blast; in most, there was no major damage.

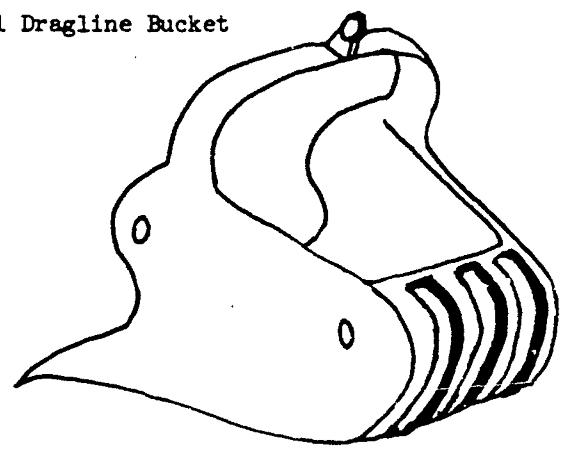
For some ordnance clearing tasks, the dragline bucket may not be a container at all, but rather a ripping tool (see Figure II-20) which serves to rake open the surface enough to expose shallowly buried ordnance. The normal dragging phase would be used, but actual ordnance recovery would be accomplished by other means.

The dragline bucket could be modified to perform a sifting function as shown in Figure II-20. This configuration would apply when the majority of the contaminating ordnance is known to be a certain size and/or shape, allowing the bucket to gather the ordnance but permitting other materials (rock, earth, sand, etc.) to pass through the rear grating of the bucket.

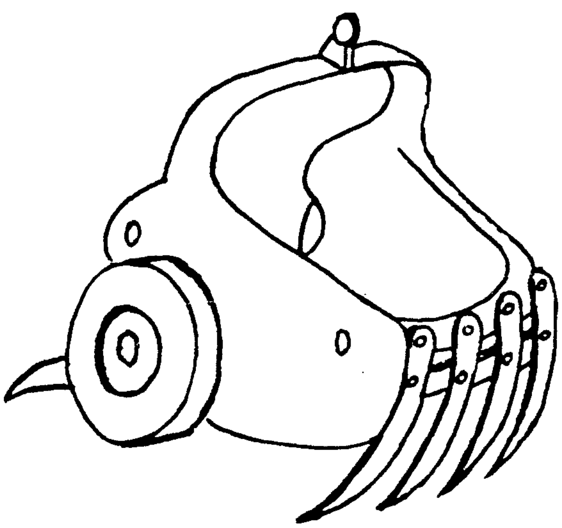
Other applications of the dragline rig pertain to range conditions where the surface is contaminated with relatively small ordnance, shrapnel or debris. The dragline bucket could be replaced by a magnetic retriever or a mechanical rock-picker; these would be positioned and pulled over the surface in much the same manner as any of the modified bucket configurations.



Conventional Dragline Bucket



Grating Modification



Ripper Modification

FIGURE II-20 Bucket Modifications.

SECTION III

R AND D PROGRAM FOR RANGE CLEARANCE SYSTEM

The information contained in this section is presented in a Development Proposal (DP) format as set forth in the recently approved Weapons System Selection and Planning Instruction.[1] Although it is not envisioned that a DP would be required for a Range Clearance System, the format is appropriate for presenting a proposed development program. It has also been determined that the mechanisms for transition from Exploratory Development (6.2) into Advanced (6.3) and/or Engineering Development (6.4) have not as yet been established by the Chief of Naval Material (DCNM for Development).

A. BACKGROUND

The joint services are charged with the responsibility for clearance/decontamination of excess military ranges prior to their being transferred to the Federal Bureau of Land Management for final disposition. Additionally, each individual service is responsible for clearance of active ranges under their jurisdiction. Specialized tools and equipment, including technical publications, are required to ensure that the joint service EOD community can safely and efficiently counter the vast amounts of unexploded ordnance on these ranges. In some areas this contamination includes test

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[1] OPNAV Instruction 5000.42 of 1 June 1974, Weapons Systems Selection and Planning.

ordnance as well as service ordnance, both U.S. and Foreign, dating back to World War I or earlier. The problem presented by this wide variety of munition types is compounded by a lack of comprehensive range records.

The current need is for a system which can accomplish mass munitions recovery and/or disposal with a supporting subsystem for maintaining accurate records of range contamination.

The initial operational capability (IOC) is required by 1977 with total system introduction in 1980.

B. ISSUES

The system will require conceptual development to be approved by all services. Certain hardware items which are included in the system can be moved immediately into advanced and engineering development upon approval of the system concept. Coordination of system development will include compatibility constraints and a determination of those tools and equipments in service use or under development which will contribute to system effectiveness. The system concept as currently envisioned will involve hardware/software development to accomplish mass recovery and removal, to be compatible with mass disposal and range useage data subsystems.

The current emphasis within the Federal and State governments, Congress and the DOD to turnover excess properties and limit the land/water areas allotted for active ranges will impose a severe workload on the Joint Service EOD community in the near time frame (1975-80). There are currently no systems under development nor alternative provisions for ameliorating this task.

The concept of a Continental Operations Range (COR) as initiated by the Air Force has application to the Army, Navy and Marine Corps. There must be provisions for EOD coverage and clearance in any range control concepts which are implemented in the future. A recent decision (1971) to prohibit deep water dumping for ammunition disposal, combined with current ecological constraints will have significant impact on future range clearance and land reclamation operations.

C. REQUIREMENT AND PROGRAM OBJECTIVES

The requirement is to develop a system which will assist the services and particularly the Joint Service EOD community in the accomplishment of range clearance and area decontamination. Range clearance normally involves the removal of surface contamination only, i.e. UXO, shrapnel, scrap, etc. Area decontamination requires the removal of all surface and sub-surface ordnance and ordnance related material down to a predetermined depth below the surface. Both operations involve the detection, location, removal and disposal of unexploded ordnance. The present rudimentary techniques cause an inordinate expenditure of man hours and result in prolonged exposure of the EOD and support personnel to hazardous conditions.

Current procedures involve the use of hand-held tools and equipment to locate and gain access to UXOs. The detection/location process is severely inhibited by extensive ferrous and non-ferrous contamination in the form of shrapnel, duds, practice ordnance and miscellaneous metallic debris. Manual removal of this contamination is hazardous due to the presence of UXOs. A mass removal and disposal capability will significantly reduce:

1. the exposure of personnel to hazardous conditions;
2. support personnel requirements; and
3. the total costs for each operation.

The objective is to provide a system which will accomplish by mechanical means, insofar as is possible, those area decontamination tasks which are the most hazardous and time consuming. The total system concept embraces all aspects of the clearance operation and must include provisions for recording and retaining range useage data on a "real time" basis. This range inventory system should allow for timely access by all concerned. Subsystem components for detection/location, access, identification, render safe, mass disposal and certain support equipment are currently under investigation or development in other related programs. This program will concentrate on the development of mass recovery and removal hardware in coordination with these on-going programs. System characteristics are outlined in Table III-1.

D. PROGRAM ALTERNATIVES

The alternative approaches investigated to date all involve personnel-intensive operations wherein each individual piece of ordnance is located, accessed and blown in place or rendered safe if the situation dictates, and removed for later disposal at a remote location. This has proven to be a time-consuming and costly operation. The only actual area decontamination rates available for cost comparison were provided by the British EOD Forces who have been engaged in clearing Maplin Sands at the mouth of the Thames River Estuary. This area is a tidal basin--flat, smooth sand-soil devoid of vegetation--ideal conditions for a clearance operation. With an average work force of 200 men, they are clearing approx- 988 acres per year to a depth of 4 1/2 feet. (See Appendix V)

TABLE III-1: System Characteristics.

Characteristic	Requirement
Performance	
Recovery	• Recover all types of munitions (excluding nuclear & CBR) up to 2,000 lbs.
Removal	• Remove munitions to safe area for final disposition
Segregation	• Segregate and stack munitions by type and/or condition
Clearance	• Clear all munitions to depth of 6 ft.
Retrieval	• Retrieve individual munitions to depth of 30 ft.
Area Coverage	• Surface area coverage rate of not more than 1 hour/acre • Clearance to depth of 1.5 ft not more than 3.5 hour/acre • Clearance to depth of 3 ft not more than 7 hour/acre • Clearance to depth of 6 ft not more than 14 hour/acre
Physical	• System performance not degraded by small rock or scrub brush cover • Operable in all types of soil
Constraints	
Physical	• Compatible with applicable EOD systems • Air transportable

<u>Constraints</u> (cont'd)

Environmental	• Operate in tropical to polar climes
	• Surface clearance only on frozen ground
	• Snow cover not to exceed 18 inches
Mobility (Prime Mover)	• Operate in rough, rocky terrain w/low scrub brush type ground cover
	• Clear 3 ft vertical obstacle -- cross 8 ft ditch
	• Climb 60° grade
Safety	• Safe stand-off distance during recovery/removal
	• Operator protection
	• Safe procedures for handling UXOs
	• Adequate safety procedures on operating components
Survivability	• Prime mover survival 100% with operator in local control 90% with operator in remote control
	• 100% survivability for remote control station (if applicable)
	• Exposed components survive 3.5 lb blast & normal fragmentation
Reliability, Maintainability, Availability	• 250 hours of continuous operation
	• Preventive/corrective maintenance by EOD personnel
	• Daily preventive maintenance not to exceed 1 hr.
	• System reliability to be at least 90% for 3000 hrs of operation

<u>Constraints</u> (cont'd)

Compatibility	• Current & programmed EOD systems as appropriate • Electrical & electronic • Military airlift • Short haul vehicular movement
Interface Requirements	• Detection/location system • Access & Retrieval system • EOD support equipment

Their procedures are almost identical to those used by the U.S. EOD community; their detection/location equipment can be evaluated as equal to or superior to that in U.S. inventory. Equating this clearance rate to the total contaminated land area under U.S. Navy jurisdiction, over 750,000 acres, results in staggering personnel implications. Additionally, recent U.S. Army estimates of near-term range clearance requirements are in excess of two million acres. The majority of this land is to be returned to state governments for various recreational and commercial uses.

The alternatives to mechanizing recovery/removal techniques appear to be threefold: (1) increase the numbers of personnel involved; (2) expand the time frame; or (3) dispose of all ordnance by detonation in place. The first two alternatives would require the employment of large numbers of highly trained military personnel to function as unskilled laborers for extended periods of time. The third alternative still requires that the ordnance be located and accessed by digging or hydraulic methods. On those ranges which have been closed because of their proximity to populated areas or ecological constraints imposed by local governments the detonation of large amounts would be unacceptable.

There have been no previous test results under actual or simulated conditions of the type of hardware envisioned for this system. There has been extensive use of massive earth moving machinery in mining and construction operations. Descriptive data, cost comparisons and capabilities of several of these equipments has been evaluated in a feasibility study which indicated that some have unique capabilities with potential application to range clearance. For example, the dragline concept appears to be particularly suited to ordnance removal/recovery with only minor modifications in equipment design.

The logistic support implications appear minimal and comparable to any heavy machinery in the various military service Engineer Force components. It is intended that the major items of machinery be of proven reliability. It is anticipated that the system can utilize many components which are already service approved.

Personnel skill levels should not exceed those already available in the various service engineer units. Estimates on numbers of personnel are dependent on final equipment configuration and service requirements. Every effort will be made to design the system to be operated by personnel assigned to EOD detachments.

E. EFFECTIVENESS AND COST COMPARISON ALTERNATIVES

Realistic effectiveness and cost comparison alternatives cannot be assessed from the data which is currently available. The exploratory phase of development will identify estimated development costs, design to cost estimates, development/production schedules and indicate risks of failure with respect to performance goals, military value and system costs.

The range clearance cost data which was made available for the study is not adequate to develop cost comparison alternatives. For example, the U.S. Air Force records of range clearance operations from 1962 to date are for surface clearance only.[2] The cost data contained in these reports (excluding military personnel pay and allowances) vary from a low of $0.14 per acre to an extreme of $4600. The variation results primarily from the amount of surface contamination

[2] Range Clearance Reports, 2701st EOD Squadron Hill AFB, Ogden, Utah.

and the type of ordnance involved. There are no comparative cost figures available for a systematic sub-surface range clearance operation similar to Maplin Sands, U.K. The Maplin Sands analysis developed in Section II D provides preliminary man-versus-machine cost/time factors, for that particular operating environment. The figures do indicate that an unmodified dragline with a bucket capacity of 15 cubic yards can excavate an acre of wet sand down to a depth of 4.5 feet in 9.12 hours at a cost of $617. This equates to a clearance rate of 0.877 acres per day at a cost of $541, working an 8-hour day. The man-day equivalent is 54 personnel at a cost of $1822, based on the daily pay rate of an E-5; per diem costs are not included. Although excavating large areas provides a high probability of total clearance, it would not be necessary or cost effective under normal circumstances. The most effective system involves a combination of search/recovery teams and a mass removal subsystem. In a large majority of the range areas which must be cleared, the mass removal system would clear the surface and shallow subsurface contamination. The remaining ordnance would be cleared by the normal procedure of search, location and selective digging. A modified dragline type of recovery system would also contribute to the effectiveness of the final phase of the clearance operation.

F. RISKS

The total system concept involves detection and location; access, render safe and retrieval; mass recovery and removal; mass munition disposal; and support hardware requirements. Only the mass recovery/removal subsystem is addressed herein for the following reasons:

1. the recovery/removal subsystem can operate independently; its effectiveness is not dependent on other subsystem components;

2. development of the recovery/removal subsystem will contribute to the effectiveness of other systems under development insofar as area decontamination and range clearance operations are concerned;

3. removal of surface and shallow subsurface decontamination by mechanical means will decrease ferrous and non-ferrous clutter by an estimated 60%, which will result in a significant increase in the effectiveness of location/detection equipment;

4. the most significant gain to be realized in range clearance is to reduce manpower costs and personnel exposure time. A mass removal/recovery system offers the greatest potential in both of these areas.

The performance capabilities of industrial machinery are well documented; the actual removal of overburden in various terrain and soil composition has been demonstrated in strip mining operation. Critical performance criteria for this removal subsystem will involve system survivability and protection of the operator. This is to be accomplished by revetment of the operator and major machinery and hardening of exposed components. The cost and feasibility of remote control operation will also be investigated during exploratory development.

In order to reduce initial investment risks, prototype test equipment will be assembled using available military vehicles such as the Army M88 Medium Recovery Vehicle or the Rough Terrain Crane for the major system component. The M88 is a full-tracked, armored vehicle which appears well suited to a dragline application with minimum

modification. Modified APCs have been successfully employed on Air Force ranges and in Picatinney Arsenal Tests as DUD retrievers. Scheduling risks will be dependent on program priority and funding.

G. OTHER FACTORS

Total system introduction is dependent on subsystem component development. With the exception of mass munitions disposal, all subsystems are under development in response to SOR 47-34R1 (SOR for Joint Service EOD Requirements). Proposed OR-01SL will replace SOR 47-34R1, when approved. Mass munitions disposal alternatives are under investigation by all services. These efforts are coordinated by the Joint Logistics Commanders' Panel on Disposal Ashore of Ammunition. The Navy AEDA (Ammunition, Explosives and Dangerous Articles) DEMIL/Disposal Program is currently investigating feasible alternatives to deep water dumping for ammunition disposal.

Program development will be coordinated through the Joint Service EOD Program Board in accordance with DOD directive 5160.62 of 24 November 1972. Additional coordination with the DOD Explosive Safety Board will be affected on an as-required basis.

H. THE DEVELOPMENT PLAN

The development plan and major milestones are outlined in Table III-2. The plan schedules milestones based on a two-year development cycle for the recovery/removal subsystem.

TABLE III-2 RANGE CLEARANCE SYSTEM

RECOVERY/REMOVAL SUBSYSTEM	TARGET DATE FOR COMPLETION												
	FY 75				FY 76				FY 77				
MAJOR MILESTONES	1	2	3	4	1	2	3	4	1	2	3	4	MAJOR CONSIDERATIONS
EXPLORATORY DEVELOPMENT													
1 - Develop Range Data		X											Representative Army, Navy, Air Force, Marine Corps Ranges
2 - Environmental Considerations		X											Terrain, Soil, Climate
3 - Define Interface Requirements			X										Compatibility constraints, Related Systems
4 - Operational Constraints			X										Manpower, Safety, Reliability, Maintainability, Performance
5 - Hardware Analysis			X										Use feasibility study data base -- Analyze alternatives
6 - Conceptual Design				X									Consider modular package and in-service equipment
7 - Feasibility Tests				X									Demonstrate feasibility model
8 - Exploratory Development Complete				X									Transition to 6.3/6.4 Program
SYSTEM DEVELOPMENT													
9 - Design Phase					X								Best alternative selected for prototype fabrication
10 - Prototype Fabrication					X								Make maximum use service approved components
11 - Initial ILS Plan						X							Personnel, Training, Logistics, Life Cycle Costs, etc.
12 - Prototype Tests						X							
13 - Develop Operational Procedures							X						
14 - Initiate Tech-Eval							X						
15 - System Rework								X					
16 - Initiate Op-Eval									X				If required
17 - Approval for Service Use										X			MTAB Function
18 - Procurement Data Package										X			
19 - Production Contract Award										X			
20 - Initial Operational Capability											X		

Note: The draft Joint Service EOD OR - 01 SL includes related subsystems requirement for Detection/Location, Access/Retrieval, and EOD Support Equipment. There is no formal program for Mass Munitions Disposal.

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NOTE: A significant number of classified documents from a variety of sources (principally from DDC and EODC) were reviewed by investigators during the course of the study. These reports served to broaden understanding of the total decontamination problem but were not essential to the analysis.

APPENDIX I

ESTIMATION OF PROJECTILE PENETRATION DEPTHS

A. Introduction

The depth of penetration of a projectile into the ground depends upon its angle of incidence, weight, velocity, size, and shape, and on the resistance of the soil. All these factors vary, complicating the task of estimating the probable depths at which various types of unexploded ordnance will be found. It is highly desirable to establish a practical basis for determining probable penetration depths from on-site soil-resistance measurements which can be made at the beginning of each range-clearance operation.

B. Impact Velocity

The impact velocity V of a projectile can be taken as its terminal velocity in descent. It can be estimated by setting its weight W equal to the air-drag force acting on it, or

$$W = C_d \left(\frac{\rho V^2}{2\,g}\right) A \qquad (1)$$

where C_d is the drag coefficient,

ρ is the weight density of air, 0.08 lb/ft³,

g is the acceleration due to gravity, 32.2 ft/sec²,

and A is the projectile's cross-sectional area, $\pi d^2/4$ for a projectile of diameter d.

For a first-order estimate, C_d can be taken as 1, and Eq. (1) can be rearranged in the form

$$V = \frac{2}{d}\sqrt{\frac{2\,g\,W}{\pi\rho}} \quad . \qquad (2)$$

For a 1000-lb. bomb of two-foot diameter, V calculated by this formula is about 500 ft/sec.

C. Penetration Distance

The penetration distance D can be estimated by setting the projectile's initial kinetic energy equal to the work done against the soil resistance R, or

$$\frac{1}{2}\left(\frac{W}{g}\right) V^2 = R\,D \qquad (3)$$

from which the penetration distance is

$$D = \frac{W\,V^2}{2\,g\,R} \quad . \qquad (4)$$

If the characteristics of the projectile are known, the accuracy of calculated values of D depends on the validity of the estimate of R.

D. Soil Penetration Resistance

One approach to the estimation of soil resistance is to consider the forces acting on the projectile equivalent to the bearing forces on a pile of the same diameter d and length L, or

$$R = \frac{\pi d^2}{4} C + \pi d L S \qquad (5)$$

where C is the compressive strength of the soil and S is the skin friction of the soil sliding past the side wall of the projectile, approximately equal to the shearing strength of the soil.[1] Typical values for a soft clay soil are $C = 750$ lb/ft^2 and $S = 100$ lb/ft^2. With these in Eq. (5), the value of R is 4860 lb for a bomb of two-foot diameter and four-foot length. Inserting this into Eq. (4), the penetration distance for a 1000-lb bomb with a terminal velocity of 500 ft/sec is 820 feet. This is obviously a gross overestimate for the lowest-drag bomb falling into the softest soil. It is evident that the static pile bearing strength of the soil accounts for a minor fraction of the penetration resistance. Energy dissipation during penetration of a projectile is undoubtedly due mainly to dynamic viscoelastic phenomena.

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[1] R.H. Karol, Soils and Soil Engineering (Prentice-Hall, 1960), p. 143.

A dynamic index of penetration resistance is the number of blows by a 140-lb weight dropping 30 inches (2.5 feet) required to drive a special probe one foot deeper into the ground.[2] In soft soil, four such blows are required to drive a probe of two-inch diameter down one foot, so the penetration resistance is determined by

$$4\ (140\ \text{lb})\ (2.5\ \text{ft}) = R_2\ (1\ \text{ft})$$

from which $R_2 = 1400$ lb. Assuming the soil resistance to be proportional to the cross-sectional area of the projectile, the resistance to penetration by a bomb of 24-inch diameter is

$$R_{24} = \left[\frac{24\ \text{in}}{2\ \text{in}}\right]^2 R_2 = 144\ (1400\ \text{lb}) = 202{,}000\ \text{lb}.$$

With this value for R in Eq. (4), the distance of penetration of a 1000-lb bomb impacting at 500 ft/sec is 20 feet. This is about half the typical bomb depth reported[3] so an alternative approach is desirable.

A soil-sounding technique more favored in Europe than in the U.S. is measurement of the load required to force a 60° cone of 1.4-inch base diameter into the ground.[4] The

[2] T.H. Wu, Soil Mechanics (Allyn and Bacon, 1966), p. 381.

[3] Commander, Naval Ordnance Systems Command, Ordnance Clearance Plan, 1972, p. 1-16.

[4] Wu, Soil Mechanics, p. 381.

resistance of a soft soil measured by this method is about 20 tons/ft². Then for a projectile of two-foot diameter, $R = (40{,}000\ \text{lb/ft}^2)\ (\frac{\pi}{4})\ (2\ \text{ft})^2 = 126{,}000$ lb. With this value in Eq. (4), a 1000-lb bomb impacting at 500 ft/sec will penetrate 31.6 feet. This is closer to the anticipated penetration depths[5] so it appears that the soil resistance measured by the cone is more representative of that encountered by a pointed projectile than that measured by driving a blunt-ended probe into the ground. Some cone-penetration resistances and the 1000-lb bomb penetration distances computed from them are tabulated below.

Soil Type[6]	Cone-Penetration Resistance (tons/ft²)	Maximum penetration by a 1000-lb bomb of 2-ft diameter impacting at 500 ft/sec (feet)
very loose	less than 20	greater than 32
loose	20 to 40	16 to 32
medium	40 to 120	5 to 16
dense	120 to 200	3 to 5
very dense	over 200	less than 3

[5] Commander, Naval Ordnance Systems Command, Ordnance Clearance Plan, p. 1-16.

[6] Wu, Soil Mechanics, p. 381.

E. Conclusions

These soil-penetration estimates for 1000-lb bombs are not of high accuracy, and cannot be the basis for predicting the depths at which these and other types of projectiles will be found, since

(1) the cone-penetration resistance or other hardness index is not known for the soils in which bomb penetrations were observed[7]

(2) terminal velocities should be obtained from ordnance manuals or other reliable sources rather than computed by Eq. (2)

and (3) the effect of off-vertical incidence has not been considered.

Nevertheless, the closeness of the maximum computed value to the empirical values is of interest.[8]

It appears that a reasonable estimate of soil-penetration resistance can be obtained by a soil-sounding technique such as the cone-penetration test or a stake-driving measurement. Such soundings can show the variation of the penetration resistance with depth; this may establish a basis for replacing Eq. (4) by a summation of terms corresponding to the sequence of soil strata encountered at a particular site. This approach merits further detailed study.

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[7] Commander, Naval Ordnance Systems Command, Ordnance Clearance Plan, p. 1-16.

[8] Ibid.

APPENDIX II

LAND RECLAMATION LAWS

The emphasis on land reclamation has been highlighted by recent changes in state and federal laws. Although these statutes are aimed at control of strip mining and other surface mining activities, they also affect the ordnance decontamination activities that may be conducted by the military services. The laws summarized here are those in effect as of October 1973. The civil authorities continue to place even more stringent requirements on surface mining operations, making it necessary to keep abreast of the changes that impinge on clearance operations that are conducted on lands under civil jurisdiction or that will be returned to public use subsequent to decontamination.

SUMMARY OF STATE SURFACE MINING AND MINED LAND RECLAMATION LAWS IN EFFECT OCTOBER 1, 1973*

State	Title or Code Citation	Minerals Covered	License and/or Permit Requirements			Bond Requirements	Reclamation Requirements	Penalty for Failure to Reclaim		Remarks
			Application	Fee	Penalty			Forfeiture of Bond	Denial of New Permit	
ALABAMA	Alabama Surface Mining Act of 1969. Effective Oct. 1, 1970	Coal, clay, sand, gravel, plus other minerals except limestone, marble, and dolomite.	Application for permit must be filed with the Dept. of Industrial Relations. Reclamation plan is required.	$250. $50 fee for amended permit.	Not less than $500 nor more than $5000. Willful misrepresentation $100 to $500.	$150 for each acre covered by the permit	Grade peaks to rolling topography; cover face of toxic material; divert water to reduce siltation, erosion or other damage to streams and natural water courses; revegetate affected land	Yes	Yes	
ARKANSAS	The Arkansas Open Cut Land Reclamation Act of 1971. Effective July 1, 1971.	Coal, clay, bauxite or other minerals except stone, sand and gravel.	Application for permit must be filed with the Arkansas Pollution Control Comm. Reclamation plan is required.	Up to 2 acres $25, 2-10 acres -$.00; 10-50 acres $500, each 50 acres above original 50 acres-$500.	Not less than $50 nor more than $1000. Each day is deemed a separate offense.	$500 for each acre affected.	Grade ridges and peaks to a rolling or terraced topography, construct earth dams where lakes may be formed; construct fire lanes on land to be reforested; strike peaks and ridges to a minimum of 20-foot at top on all land which is to be seeded for pasture.	Yes	Yes	
COLORADO	The Colorado Open Cut Land Reclamation Act of 1969 as amended. Effective July 1, 1972.	Coal	Application for permit must be filed with the Land Reclamation Board. Reclamation plan is required.	Basic fee-$50 plus $15 for each acre to be affected. Amended permit $10 plus $15 per acre.	Not less than $50 nor more than $1000.	The Land Reclamation Board determines the amount of bond necessary to insure Compliance with the law.	The operator, subject to approval of the Land Reclamation Board, determines the use for which the land is to be reclaimed. Reclamation requirements vary according to proposed land use.	Yes	Yes	
	Colorado Revised Statutes, 1963 as amended by Chapter 242, Sessions Laws of 1969.	All minerals except coal.	The operator is required to file a notice of activity with the Director, Bureau of Mines. Upon approval of the proposed mining activity the operator may be permitted to engage in mining.			Commissioner of Mines determines whether or not a performance bond is required.	Whenever possible, type of reclamation to be determined through agreement between the Commissioner of Mines and the operator.	Yes	Yes	
GEORGIA	Georgia Surface Mining Act of 1968. Effective Jan. 1, 1969.	Clay, stone, gravel, sand, phosphate, rock, metallic ore, and any other solid substance of commercial value found in natural deposits on or in the earth.	Application for license must be filed with the Surface Mined Land Use Board. Reclamation plan is required.	Less than 50 employees $100 annually. More than 50 employees $100 plus an additional $50 for each increment of 50 employees. Maximum annual license fee not to exceed $500	Fine of not less than $100 nor more than $1000 for each offense.	To be fixed by the Board of Reclamation not less than $100 nor more than $500 per acre. The minimum accepted bond for any operation is $500.	Grade peaks and ridges to a rolling topography, cover exposed toxic area or mineral solids with a minimum of two (2) feet of soil capable of supporting a permanent plant cover.	Yes	Yes	
IDAHO	The Idaho Surface Mining Act as amended. Effective March 14, 1973.	Coal, stone, sand, gravel, metalliferous and non-metalliferous type ore and any other similar solid type material or substance of commercial value.	No permit is required. Persons desiring to conduct exploration and surface mining operations must submit and have approved by the Board of Land Commissioners. A reclamation plan is required.		Not less than $100 nor more than $1000 per day. Wilful violation--not less than $1000 nor more than $5000 or imprisonment not to exceed one year or both.	The Board of Land Commissioners decides whether a bond is to be filed and what the amount should be.	Level ridges of overburden to a minimum width of 10 feet at the top; level peaks to a minimum of 15 feet at the top. Prepare affected land to control erosion and run-off; conduct vegetation on mined areas, overburden piles and abandoned roads.	Yes	Yes	
ILLINOIS	The Surface-Mined Land Conservation and Reclamation Act. Effective Sept. 17, 1971.	All minerals	All operations of 10 acres and exceeding 10 feet in depth must have a permit from the state Department of Mines and Minerals. Reclamation plan is required.	$50 plus $25 for every acre to be affected.	Not less than $50 nor more than $1000. Each day is deemed a separate violation	Between $600 and $1000 per acre.	Grade peaks and ridges to a rolling topography; construct earth dams where lakes may be formed, bury acid forming materials; construct access roads through areas to be afforested; plant trees, shrubs, grasses, or legumes to provide suitable vegetative cover.	Yes	Yes	

* Source - U.S. Bureau of Mines, Division of Environment.

(cont'd) STATE ENACTED SURFACE MINING LAWS

INDIANA	Chapter 344 Acts of 1967 Effective Jan. 1, 1968.	Coal, clay, and shale	Application for permit must be filed with the Rec. forester. Rec. plan is required.	$50 plus $15 per acre.	$1000-$5000 fine	The greater of $2000 or $300 times the number of acres for which the permit is issued	Reduce peaks to a rolling topography; impound water and cover exposed face of seam with water or earth. Revegetation to conform to land use objectives.	Yes	Yes	
IOWA	An Act Relating to Surface Mining, Chapter 114, Acts of 62nd General Assembly.	Coal, gypsum, clay, stone, sand, gravel, or other ores or mineral solids.	License must be obtained from the Dept. of Mines and Minerals	$50 annual fee $5 renewal fee. Each mine site must be registered. Registration fee to be determined by the Dept. of Mines and Minerals	$50 to $500 fine or 30 days imprisonment or both	Equal to the estimated cost of rehabilitating each site	Grade peaks and ridges to a rolling topography, construct earth dams in final cuts, cover acid forming material. Dispose of refuse by burial	Yes	Yes	
KANSAS	Mined Land Conservation and Reclamation Act. Effective July 1, 1968	Coal	Application for permit must be filed with the Mined Land Conservation and Reclamation Board. Reclamation plan is required.	$50.	Not to exceed $250. Each day considered a separate offense.	Not less than $200 nor more than $500 with a $2000 minimum.	Grade overburden of each pit to a substantially flat surface. Water impoundment is encouraged. Cover face of coal or other minerals with compacted non-acid bearing and non-toxic materials to a distance of at least 2 feet. Revegetate the affected area with seeds plants or cutting of trees, shrubs or grasses.	Yes	Yes	
KENTUCKY**	Chapter 350, Kentucky Revised Statute. Effective June 16, 1966	All minerals.	Application for permit must be filed with the Div. of Reclamation. Reclamation plan is required.	Coal: $150 plus $35 per acre. License fee for clay, fluor spar, sand, gravel, stone and rock asphalt $100 per yr. Permit fee for fluor spar, sand, gravel, stone and rock asphalt $25 per yr.	$100 to $1000 fine. Each day's violation constitute a separate offense. $500 to $5000 for willful violation of the law	$500 to $1000 per acre	Backfill to top of highwall and grade to original contour, eliminate spoil peaks, impound water, bury acid forming materials, plant trees, shrubs, grasses, and legumes upon affected area to provide a suitable vegetative cover.	Yes	Yes	
MAINE	Conservation and Rehabilitation of Land. Effective June 1, 1971	Clay, peat, stones, minerals, ores, topsoils or other solid matter except sand and gravel.	The operator must file a mining plan with the Maine Mining Comm. which must be approved prior to start of operation.	$50 plus $25 per acre, but not to exceed total of $500.	Not more than $100 for each day the violation continues.	Not less than $100 nor more than $1500 per acre	The type of reclamation performed is determined by the Maine Mining Commission.	Yes	No	
MARYLAND**	Strip mining laws of the State of Maryland 1971. Effective July 1, 1971.	Coal	Application for license and permit must be filed with the Director, Bur. of Mines. Reclamation plan is required	License fee $100 plus $10 renewal. A special reclamation fee $30 per acre must accompany permit application	License $5000 to $10,000 or 6 months imprisonment or both. Permit--$500 to $5000 fine.	$400 per acre, $3000 minimum.	Grade spoil banks to reduce depressions between peaks to restore terrain to as near normal as possible, satisfactory to the Director. Revegetation is required. The operator is required to deposit a revegetation bond of not less than $125 per acre of land affected.	Yes	Yes	
MICHIGAN	Act No. 92, Metallic Mining Lands, Reclamation. Effective July 20, 1970. Amended April 27, 1972.	All minerals.				The operator may be required to furnish a performance bond or other security or assurance.				The Act authorizes the conduct of a comprehensive study and survey to determine the extent and type of regulation of mining areas necessary in the public interest. On completion of the study and survey, rules may be issued pertaining to mining operations.

TABLE 19 (cont'd) STATE-ENACTED SURFACE MINING LAWS

MINNESOTA	Minnesota Statutes, Chapter 93, Mineral Lands, Section 93.44, Reclamation of Lands. Enacted May 1968.	Metallic minerals.	---	---	---	The Commissioner of Natural Resources determines whether or not a performance bond is required.	---	---	---	This Act establishes an "Iron Range Trail" and gives the Commissioner of Natural Resources authority to conduct a comprehensive study and survey to determine the extent to which regulation of mining areas is necessary in the interest of the general public, and to adopt rules and regulations pertaining to mining operations conducted subsequent to the effective date of such rules and regulations.
MISSOURI	An Act Relating to the Reclamation of Certain Mining Lands. Effective Sept. 28, 1971.	Coal and barite.	Permit must be obtained from the Land Reclamation Commission. Reclamation plan is required.	$50 plus $17.50 per acre.	Not to exceed $1000 per day. Each day constitutes a separate violation.	Not less than $300 for coal and $200 for barite, nor more than $700 for coal and $500 for barite per acre. $2000 minimum.	Future use of the land determines the type of reclamation to be performed.	Yes	Yes	
	The Land Reclamation Act. Effective Sept. 28, 1971.	Clay, limestone, sand and gravel.	Permit must be obtained from the Land Reclamation Comm. Reclamation plan is required.	$50 plus $17.50 per acre.	Not less than $50 nor more than $1000. Each day constitutes a separate offense.	$500 per acre.	Future use of the land determines the type of reclamation to be performed.	Yes	Yes	
MONTANA	The Montana Strip Mining and Reclamation Act. Effective March 16, 1973.	Coal, clay, phosphate rock and uranium.	Permit must be obtained from the Dept. of State Lands. Reclamation plan is required.	$50 fee to accompany mining permit application. $100 fee to accompany prospecting permit application.	Each violation--not less than $100 nor more than $1000, and an additional $100 to $1000 for each day the violation continues. Willful violation--$500 to $5000 each day violation continues.	Not less than $200 nor more than $2,500 per acre with a $2000 minimum.	In addition to grading, backfilling, highwall reduction, topsoiling and reclamation, the operator must: bury all toxic material; seal off breakthrough of water creating a hazard; impound and drain runoff water to reduce soil erosion, damage to grazing and agricultural lands, and pollution of surface and subsurface waters; and remove or bury all metal, lumber, and other refuse.	Yes	Yes	
	The Open Cut Mining Act. Effective March 16, 1973.	Bentonite, and sand and gravel.	Application for a contract must be made by the operator to the State Board of Land Commissioners if the planned operation involves removing 10,000 cubic yards or more of product or overburden. Reclamation plan is required.	Contract application must be accompanied by a fee of $50.	Not less than $500 nor more than $1000. Each day of violation constitutes a separate offense.	Not less than $200 nor more than $1000 per acre.	Reclamation must be carried out in accordance with the previously approved reclamation plan which requires that the land be reclaimed for specified uses including forest, pasture, orchards, cropland, residence, recreation, industry, or wildlife habitat. Reclamation requirements include: establishment of vegetative cover; control water drainage; grading; removal or burying metal or waste, and revegetation of affected area.	Yes	Yes	
	Montana Hardrock Mining Reclamation Act. Effective Sept. 15, 1971.	Any ore, rock or substance other than oil, gas, bentonite, clay, coal, sand, gravel, phosphate rock or uranium.	Exploration license and Development permit must be obtained from the State Board of Land Commissioners. Reclamation plans are required.	Exploration license - $5.00. Development permit $25.	Violation of Act - Not more than $1000 or 6 - months imprisonment or both.	Not more than $500 per acre.	Reclamation of the affected land must be performed in accordance with the previously approved reclamation plan which contains measures for surface gradient restoration suitable for proposed land use; revegetation or other surface treatment; public health and safety; disposal of mining debris; diverting water to prevent pollution or erosion; reclamation of stream channels and banks to control erosion, siltation, and pollution.	Yes	Yes	
NEW MEXICO	Coal Surface Mining Act. Effective Feb. 29, 1972.	Coal	Application for permit must be filed with the Coal Surface Mining Comm. A mining plan must accompany permit application	$50 application fee. $10 initial acreage fee. Annual fee of $10 per acre for each acre affected during the preceding year.	$1000 for each day violation continues.	The Surface Coal Mining Commission may require an operator to file a bond in an amount sufficient to insure compliance.	Reclamation to be carried out in accordance with the previously approved mining plan which includes: grading the affected area; revegetating the affected area; and revegetation and grading time schedules.	---	---	

TABLE 19 (cont'd) STATE-ENACTED SURFACE MINING LAWS

NORTH CAROLINA**	The Mining Act of 1971. Effective June 11, 1972.	Soil, clay, coal, stone, sand, gravel, phosphate, rock, metallic ore, and any other solid material or substance.	Application for a permit must be filed with the Dept. of Natural and Economic Resources. Reclamation plan is required.	No fee required. Permit will be granted if reclamation plan is approved.	Willful violation $100 to $1000 for each day constitutes a separate violation.	Up to 5 acres $2,500; 5 to 9 acres $5,000, 10 to 24 acres $12,500, 25 or more acres $25,000	Reclamation of the affected land is to be performed in accordance with the previously approved reclamation plan.	Yes	Yes	
NORTH DAKOTA	Chapter 38-14 North Dakota Century Code, as amended. Effective July 1, 1973.	Coal, clay, stone, sand, gravel, or other minerals.	Application for a license must be filed with the Public Service Comm. for all operations exceeding 10 feet in depth. Reclamation plan is required.	Up to 10 acres $25 plus $10 times the number of acres to be affected between 2 and 10. 11 to 50 acres $100 plus $10 times the number of acres between 11 and 50. More than 50 acres $275 plus $10 times the number of acres in excess of 50 acres.	$50 to $1000 each day constitutes a separate violation.	$500 per acre.	Regrade affected area to approximate original contour, or rolling topography or topography for higher end use; spread topsoil or other suitable soil material over the regraded area to a depth of 2 feet. Impound or treat runoff water to reduce soil erosion, damage to agricultural lands and pollution of streams; back-slope final cuts and end walls to an angle not to exceed 35 degrees from the horizontal (operator may propose alternative to backfilling if consistent with the Act); remove or bury all debris; and sow, set out, or plant seeds, plants, cuttings or trees, shrubs, grasses, or legumes	Yes	Yes	
OHIO	Ohio Revised Code. Chapter 1513, as amended-Reclamation of strip mined land. Effective April 10, 1972.	Coal	Application for license must be filed with the Div. of Forestry and Reclamation. Reclamation plan is required.	$150 plus $30 per acre.	Mining without a permit $5000 plus $1000 per acre of land affected. Exceed limits of license $1000 per acre of land affected that is not under license. Willful misrepresentation $100 to $1000 or 6 months. Violation of any other provision $100 to $5000 or 6 months in prison or both.	Not less than $5000.	Contour the area of land affected; replace topsoil; cover all toxic or acid producing material; prevent pollution of waters, erosion, land-slides, flooding, and the accumulation or discharge of acid water; and plant and grow vegetative covering.	Yes	Yes	
OKLAHOMA**	The Mining Lands Reclamation Act. Effective June 12, 1971.	Coal, clay, stone, sand, gravel, asphalt, copper, granite, gypsum, lead, marble, salt, shale, tripoli, volcanic ash, zinc or any other material.	Application for permit must be filed with the Dept. of Mines and Mining. Reclamation plans are required.	$50	$50 to $1000. Each day constitutes a separate offense.	$350 to $650 per acre. $5000 minimum.	Grade to reduce peaks to a rolling topography. Construct earth dams in final cuts, impound water. Cover exposed face of mineral seam where acid forming materials are present to a depth of 3 feet with earth or spoil material. Different planting requirements for different land uses are specified.	Yes	Yes	
OREGON	An Act relating to mining. House Bill 3013. Oregon Legislative Assembly-1971. Regular Session. Effective July 1, 1972.	Soil, coal, clay, stone, sand, gravel, metallic ore and any other solid substance excavated for commercial, industrial or construction use.	Application for a permit must be filed with the State Dept. of Geology and Mineral Industries. Reclamation plan is required.	Basic fee $100. Annual fee of $25.	Fine of not more than $1000.	Not to exceed $3000 per acre of land to be surface mined.	Reclamation of the affected land must be performed in accordance with previously approved reclamation plan which contains measures for the protection of the natural resources of adjacent lands; rehabilitation of surface-mined lands; control discharge of contaminants and disposal of refuse; rehabilitation of stream channels and banks to minimize erosion, sedimentation and other factors of pollution.	Yes	Yes	
PENNSYLVANIA**	Surface mining Conservation and Reclamation Act. Effective Jan. 1, 1972.	All minerals.	Application for permit must be filed with the Dept. of Environmental Resources. Reclamation plan is required.	$500. Annual renewal fee of $300.	$5000 or an amount of not less than the total profits derived as a result of unlawful activities, together with the cost of restoring the land to its original condition or 1-year imprisonment or both.	Not less than $500 nor more than $1000 per acre based upon the number of acres in each operation.	Reclamation to be performed in accordance with the approved reclamation plan including the planting of trees, grasses, legumes or shrubs where conditions permit.	Yes	Yes	
SOUTH CAROLINA**	The South Carolina Mining Act. Effective July 1, 1974.	Soil, clay, coal, stone, gravel, sand, phosphate rock, metallic ore, and other solid substance or material found in natural deposits.	Application for a permit must be filed with the Land Resources Conservation Comm. Reclamation plan is required	....	Not less than $100 nor more than $1000 for each offense. Each day of continued violation is considered a separate offense.	Less than 5 acres-$2500, 5 to 9 acres-$5000, 10 to 24 acres-$12,500, 25 or more acres $25,000 or a greater amount if necessary to insure reclamation	Reclamation to be performed in accordance with the previously approved reclamation plan which requires: final slopes to be at such angle as to minimize the possibility of slides; overburden and spoil to be left in a configuration which is in accordance with good conservation practices, suitable drainage to prevent noxious, odious, or foul water from collecting, and use of specific type vegetative cover and method of its establishment.	Yes	Yes	
SOUTH DAKOTA	Surface Mining Land Reclamation Act. Effective July 1, 1971	Coal, clay, stone, sand, gravel and other minerals.	Application for a permit must be filed with the State Conservation Comm. Reclamation plan is required	$50. Annual renewal fee of $25.	Not more than $1000. Each day constitutes a separate offense	Amount sufficient to cover the cost of reclamation as determined by the Commission.	Reconditioning or rehabilitating affected land shall be carried out in accordance with the plan approved by the State Conservation Commission	Yes	Yes	

TABLE 19 (cont'd) STATE-ENACTED SURFACE MINING LAWS

TENNESSEE**	*The Tennessee Surface Mining Law.* Effective March 23, 1972.	Coal, clay, stone, gravel, sand, phosphate rock, metallic ore and any other solid material or substance except limestone, marble, and dimension stone.	Application for permit must be filed with the Commissioner of the Dept. of Conservation. Reclamation plan is required.	$250 plus $25 per acre not to exceed $2500.	$1000 to $5000 or imprisonment not to exceed 1 year or both.	Not less than $600 per acre for coal and $400 per acre for other minerals.	The law sets forth different reclamation requirements for different minerals. The State statute should be consulted to obtain complete details.	Yes	Yes	
VIRGINIA	Chapter 16, Code of Virginia of 1950 and 1968 Cumulative Supplement. Effective June 27, 1966.	Other minerals	Application for permit must be filed with the Div. of Mines, Dept. of Labor and Industry. Reclamation plan is required.	$6 per acre maximum $150.	$1000 or 1 year imprisonment or both.	$50 per acre with a $1000 minimum.	Remove all debris, grade the affected area and preserve access roads; and plant trees, shrubs, and grasses where revegetation is practicable.	Yes	Yes	
	Chapter 17, Title 45. 1a, Code of Virginia 1950 as amended. Effective April 10, 1972.	Coal	Application for permit must be filed with the Dir., Dept. of Conservation and Economic Development. Reclamation plan is required.	Prospecting permit $6 per acre. Mining permit-$6 per acre. Annual Renewal fee $2.	Not more than $1000 or 1 year in jail or both.	Prospecting bond $300 per acre. Mining bond-not less than $200 nor more than $1000 per acre with $2500 minimum unless the amount of land disturbed is less than 5 acres, then the minimum bond will not be less than $1000.	Reclamation to be performed in accordance with the previously approved reclamation plan.	Yes	Yes	
WASHINGTON	Surface Mined Land Reclamation Act. Chapter 64, Laws of 1970. Effective Jan. 1, 1971.	Metallic ore, coal, clay, stone, sand, gravel, and any other similar solid material.	Application for permit must filed with the Dept. of Natural Resources. Reclamation plan is required.	$25 per year plus $5 per acre exceeding 10 acres which was disturbed during the previous permit year.	No amount specified.	$100 to $1000 per acre.	Reduce peaks and depressions to a gently rolling topography. Bury acid forming material. Grading and backfilling to be done with non-noxious, nonflammable solids. Vegetative cover required appropriate to the future use of the land.	Yes	Yes	
WEST VIRGINIA**	Art 6, Chapter 20, The Code of West Virginia, amended. Effective March 13, 1971.	Coal, clay, flagstone, gravel, sandstone, shale, iron and ore, and any other metal or metallurgical ore.	Application for permit must be filed with the Dept. of Natural Resources. Reclamation plan is required.	$500; annual renewal fee $100. A prospecting fee of $300 is required.	$100 to $1000 or 6-month imprisonment or both. Willful violation not be less than $10,000 or imprisonment not exceeding 6 months or both.	$500 per acre.	Cover the face of coal and disturbed area with material suitable to support vegetative cover; bury acid forming materials, toxic material, or materials constituting fire hazard; impound water. Bury all debris. The law also contains requirements for regrading surface mined areas where benches result specifying the maximum bench width allowed. On land where benches do not result complete backfilling is required but shall not exceed the original contour of the land. The backfilling shall eliminate all highwalls and spoil peaks. Planting is required.	Yes	Yes	
WYOMING	The Wyoming Environmental Quality Act. Art. 4, Land Quality. Effective July 1, 1973.	Coal, clay, stone, sand, gravel, bentonite, scoria, rock, pumice, limestone, ballast rock, uranium, gypsum, feldspar, copper ore, iron ore, oil shale, trona and any other material removed from the earth for reuse or further processing.	Application for permit must be filed with the Administrator Div. of Land Quality. Reclamation plan is required.	Minimum fee for mining permit $100 plus $10 for each acre listed in the requested permit. Maximum fee shall not exceed $2000. Amended permit fee $200 plus $10 per acre $2000 maximum. License fee for mineral exploration $25.	$1000 for each day the violation continues.	Not less than $10,000 except for scoria or jade, sand and gravel in which case the bond is determined by the Admin. but will not be less than $200 per acre.	Reclamation to be performed in accordance with the previously approved reclamation plan which requires contouring to accommodate predetermined use; backfill or grade, and replace topsoil, or approved subsoil, which has been segregated and preserved, replace native or superior self regenerating vegetation and prevent the pollution of surface and subsurface waters during mining and reclamation for five years after the operation has terminated.	Yes	Yes	

** Member of the Interstate Mining Compact.

SCITEK, INC.

STATE ENACTED SURFACE MINING LAWS

YEAR ENACTED OR AMENDED

STATE		1965	1966	1967	1968	1969	1970	1971	1972	1973
ALABAMA							*			
ARKANSAS						*		A		
COLORADO						*			A	
GEORGIA					*					
IDAHO								*		
ILLINOIS		0		A				A		
INDIANA		0		A						
IOWA					*					
KANSAS					*					
KENTUCKY		0	A							
MAINE						*				
MARYLAND		0		A				A		
MICHIGAN							*			
MINNESOTA						*				
MISSOURI								*		
MONTANA				*		A		A		
NEW MEXICO									*	
NORTH CAROLINA								*		
NORTH DAKOTA							*			
OHIO		0							A	
OKLAHOMA				*				A		
OREGON									*	
PENNSYLVANIA		0			A		A	A		
SOUTH CAROLINA										*
SOUTH DAKOTA								*		
TENNESSEE				*					A	
VIRGINIA			*						A	
WASHINGTON							*			
WEST VIRGINIA		0		A				A		
WYOMING						*				
TOTAL	30	7	1	3	3	5	4	4	2	1

0 = Law Enacted Prior to 1965
* = Original Enactment
A = Amended

APPENDIX III

CHARACTERISTICS OF SUBSURFACE MATERIAL

In the search and recovery of ordnance that has penetrated the surface of the impact range to the extent that excavation is required for recovery, the nature of the overburden must be determined. An interesting relationship has been drawn between the measurement of seismic velocity in certain materials and the ease with which that material can be ripped (loosened) prior to scraper and dozer operations. This relationship is illustrated by Figure III-1.

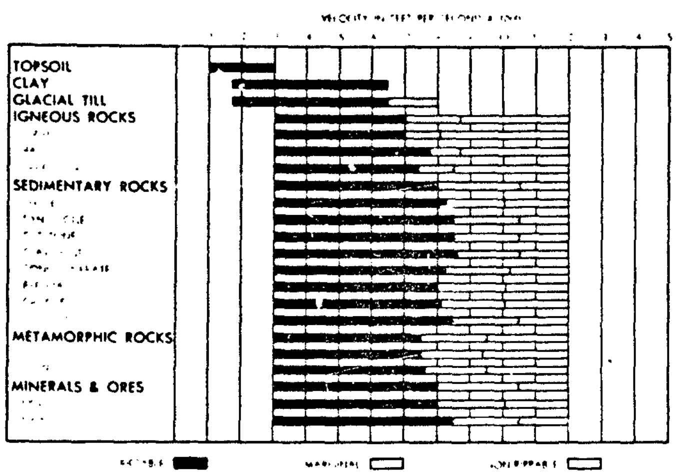


FIGURE III-1: The Relationship Between Rippability and Seismic Velocity for Various Materials.

When considering the use of shovels for major excavation, the data shown in Table III-1 will assist in the determination of degree of difficulty that would be encountered for various overburden materials. Table III-2 serves as a guideline for determining the cutting (or digging) power required for common subsurface materials.

TABLE III-1: Approximate Dipper Efficiency for Varying Classes of Material.

CONDITIONS: Digging face of sufficient length to allow dipper or bucket to obtain loads as given. Allowance must be made for smaller dipper loads when digging in shallow bank, especially with large capacity dippers. Higher dipper factors than those shown below can ordinarily be used for large strippers, shovels or large draglines.

Easy Digging	Medium Digging	Hard Digging	Rock
Shovel Dipper Factor 85% to 100%	Shovel Dipper Factor 80% to 90%	Shovel Dipper Factor 70% to 80%	Shovel Dipper Factor 40% to 60%
Loose, soft, free running materials. Close lying, which will fill dipper or bucket to capacity and frequently provide heaped load. Overload compensates for swell of material.	Harder materials that are not difficult to dig without blasting, but break up with bulkiness causing voids in dipper or bucket.	Materials requiring some breaking up by light blasting or shaking. More bulky and somewhat hard to penetrate, causing voids in dipper or bucket.	Blasted rock, hardpan and other bulky materials, which cause considerable voids in dipper or bucket and are difficult to penetrate
Dry sand or small gravel. Moist sand or small gravel. Loam. Loose earth. Muck. Sandy clay. Loose clay gravel. Cinders or ashes. Bituminous coal. Very well blasted material.	Clay—wet or dry. Coarse gravel. Clay gravel, packed. Packed earth. Anthracite coal.	Well broken limestone, sand rock and other blasted rocks. Blasted shale. Ore formations (not of rock character) requiring some blasting. Heavy wet, sticky clay. Gravel with large boulders. Heavy, wet gumbo. Cemented gravel,	Hard tough shale. Limestone. Trap rock Granite. Sandstone. Taconite. Conglomerate. Caliche rock. Any of these blasted to large pieces mixed with fines and dirt Tough, rubbery clay that shaves from bank

TABLE III-2: Specific Cutting Forces of Virgin Material.

Material type	Specific cutting forces, kg/cm	Material type	Specific cutting forces, kg/cm
Earth......................	10- 30	Sandstone (hard digging)....	160-280
Loess......................	20- 40	Gypsum......................	50-130
Sand (fine, coarse, wet,		Lime.......................	30-120
or dry)..................	10- 40	Phosphate..................	80-200
Clayey sand................	10- 50	Marl.......................	60-140
Gravel, fine...............	20- 50	Limestone..................	100-180
Gravel, coarse.............	20- 80	Weathered granite..........	50-100
Sand, loam and wet loam....	20- 60	Alluvial, light consolidation	30- 60
Dry loam...................	20- 80	Alluvial, heavy consolidation	70-150
Clay, wet..................	30- 65	Alluvial, medium	
Clay, dry..................	50-120	consolidation.............	50- 80
Clay, schistose............	35-120	Hard coal, normal..........	50-100
Sandy clay.................	20- 65	Hard coal, frozen..........	100-160
Clayey slate...............	50-160	Lignite....................	20- 70
Slate......................	70-200	Brown iron ore.............	190-210
Sandstone (easy digging)...	70-160		

Material weights are of interest in the excavation and hauling phases of a clearance operation. Table III-3 lists representative weights of the common overburden materials.

TABLE III-3: Material Weights.*

Material	Lb/cu yd (Bank)	Lb/cu yd (Loose)	% Swell
Caliche	2430		
Cement, Portland	2700	2250	20
Cinders, blast furnace	1540		
Coal, ashes and clinkers	1080		
Clay, compact natural bed	2940	2210	33
Dry excavated	1850		
Clay and gravel, Dry	2700	1930	40
Wet	3090	2200	40
Coal, Anthracite	2300	1700	35
Bituminous	1900	1410	35
Coke		650– 850	
Concrete	3240–4100	2330–2950	40
Concrete, Wet		3500–3750	
Copper ore	3800	2800	35
Earth, Dry Loam	2100	1550–1830	15–35
Moist	2700	2080–2250	20–30
Wet	3370	2700–2800	20–25
Earth, sand, gravel	3100	2640	18
Earth and rock	2500–3200	1920–2460	30
Granite	4500	2520–3000	50–80
Gravel, Dry, loose		2570	
Wet, loose		3200	
Dry, ¼"–2"		2840	
Wet, ¼"–2"		3380	
Pit run (graveled sand)		3240	
Gypsum	4500	2700	65
Limestone	4400	2660	65
Rock, well blasted	4000	2680	50
Sandstone	3900	2600	50
Sand, Dry	3250	2900	12
Moist	3400	2980	14
Wet	3600	3200	14
Sand and Gravel, Dry	3320	2920	14
Wet	3900	3380	16
Shale, riprap	2800	2100	33
Slag	3670	2970	24
Stone, crushed	3240–3920	2400–2900	35
Taconite	4050–5400	2900–3860	40
Trap rock	5000	3340	50

* Some of the above material weights vary in accordance with moisture content.

APPENDIX IV

CHARACTERISTICS OF COMMERCIAL EARTH MOVING EQUIPMENT

The characteristics of commercial earth moving equipment were reviewed to determine the equipment that might be suited to range clearance operation. The information contained herein summarizes the results and outlines considerations involved in the selection of specific machinery.

A. EXCAVATING EQUIPMENT

A summary comparison of equipment that might be used in range clearance is shown in Table IV-1.

1. Front-end Bucket Loaders:

   consider when-

   a. extreme mobility (compared with shovels) is desired;

   b. large hauling capacity is not a factor;

   c. dipper capacity of 3 to 4 cubic yards is adequate;

   d. digging requirement is low enough for direct-drive machinery.

2. Tractor Shovel, Crawler:

   consider when-

   a. low ground-bearing pressure is desired;

   b. high maneuverability is required;

   c. strong digging ability is desired;

   d. good steep slope capability is desired;

   e. travel speed is not a requirement;

   f. travel is not over abrasive material.

TABLE IV-1: Summary of Excavating Equipment.

		Shovels							
		Front Loader	Loading	Stripping	Dragline	Scraper	Bucket-wheel	Dredge	Hydraulicking
Production Rate	Low	1			2	1			
	Medium	2	1	1	1	2	2	1	2
	High		2	2	1		1	2	1
Material Handled	Rough		1	1	2				
	Medium	1	1	1	1	2	2	2	3
	Soft	1	1	1	1	1	1	1	1
Maneuverability Required	Good	1			2	1			
	Fair	1	2	2	1	1	3	2	
	Poor	1	1	1	1	1	2	1	1
Ground Conditions	Good	1	1	1	1	1	1		
	Wet, Soft	2	1	1	2	2	3	1	1
	Frozen		3	3	3				1
Cost Allowance	High	1	2	2	1	1	1	1	
	Medium	1	1	2	1	1	2	1	1
	Low	1	1	1	2	1		3	2

1. Should be considered.
2. May be considered.
3. May be considered under certain conditions.

3. Tractor Shovel, Four-wheel Drive:

   consider when-

   a. high degree of mobility is required;
   b. low maintenance cost is required;
   c. good maneuverability is not a factor;
   d. digging and transporting its own load is desired;
   e. high ground-bearing pressure is not a factor;
   f. performance will be confined to gentle slopes.

4. Power Shovel, Loading and Stripping:

   consider when-

   a. high production rate is desired;
   b. diverse material is to be handled;
   c. positive control is required for dipper and drive;
   d. low operator fatigue is a factor;
   e. low cycle time is important;
   f. flexibility and maneuverability are not factors;
   g. water seepage is not present;
   h. supporting equipment is available for material disposal.

Table IV-2 shows the outputs available from some of the larger power shovels.

5. Draglines:

   consider when-

   a. greater reach and dumping radius than shovels is required;
   b. compensation is required for pitches and rolls in clearance area;
   c. ease of maneuverability (compared with shovels) is desired;
   d. some water runoff and seepage is present;
   e. it is advantageous to work above or below grade;

TABLE IV-2: Output--Large Revolving Shovels.

Type of Shovel	Dipper Cap'y.	Approx. Cycle Time Seconds Ave. Conditions 90° Swing				Estimated Practical Output Cu Yds per 50 min hr (83% Eff.)			Quarry Loading—Yds & Tons per hr Blasted Rock—(75% Eff.)					
									60% DF		50% DF		40% DF	
		Easy Dig.	Med. Dig.	Hard Dig.	Rock Dig.	Easy Digging 90% DF	Med. Digging 80% DF	Hard Digging 70% DF	Cu	Tons*	Cu Yds	Tons*	Cu Yds	Tons*
Quarry and Mine Shovels	4½	21	25	29	33	580	430	325	220	495	185	415	145	325
	6	22	26	30	34	735	555	420	285	640	240	540	190	430
	8	23	27	31	35	940	710	540	370	830	310	700	245	550
Stripping Shovels	18	50	55	60		975	785	630						
	28	50	55	60		1510	1220	980						
	40	50	55	60		2150	1750	1400						
	60	50	55	60		3230	2620	2000						
						85% DF 75% Eff.								
Coal Loading Shovels	8	23				800 Tons								
	10	24				955 Tons								

*Solid Rock—1 Cu Yd = 4500 lbs. DF = Dipper Factor. Eff. = Operating Efficiency.

f. highly skilled operators are available;

g. high cycle times can be tolerated;

h. small amounts of load spillage can be tolerated.

General specifications for draglines are shown in Table IV-3. Dragline outputs are affected by swing and digging depth as shown in Figure IV-1 and by type of material as shown in Figure IV-2.

Among excavating equipment, these machines rank medium in production rate, high in ability to handle rough or soft material, fair in maneuverability and medium in cost of operation. When used for moving sand, sandy clay and small gravel they will give a bucket loading factor of about 90%. Heavy ground cover and moderate shrub growth will reduce the loading factor to about 85%. When considering

TABLE IV-3: Dragline Buckets.

Rated Bucket Size cu yd	Actual cu ft	Height		Approx. Weight	
		Dumping	Carrying	Empty	Loaded
7	210	20'-6"	15'-3"	14,300	35,300
9	270	21'-3"	15'-3"	17,600	44,600
11	330	22'-0"	15'-3"	21,250	54,250
12	360	22'-3"	15'-6"	24,150	60,15[illegible]
13	390	22'-3"	15'-6"	26,100	65,1[illegible]
14	420	22'-6"	15'-6"	28,400	70,400
20	600	28'-0"	20'-0"	42,000	102,000
25	750	31'-0"	23'-0"	51,000	126,000
30	900	34'-0"	25'-0"	62 [illegible]00	152,000
35	1050	35'-0"	27'-0"	71,000	176,000

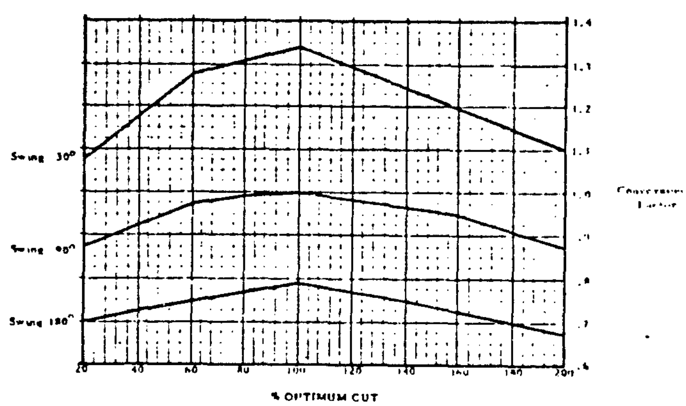


FIGURE IV-1: Effect of Swing and Digging Depth on Dragline Output.

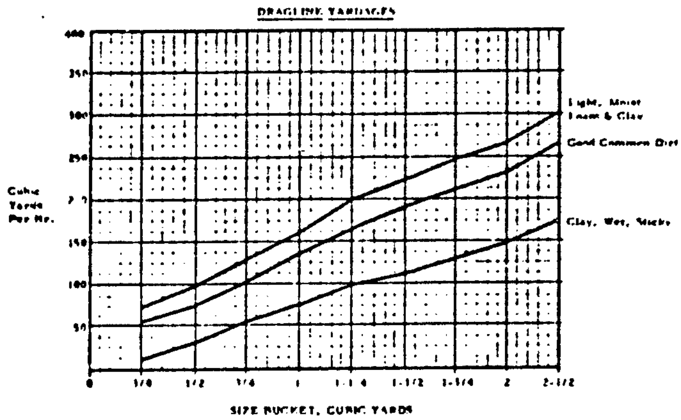


FIGURE IV-2: Effect of Type of Material On Dragline Output.

operation in sand, average material weights would be 2,900 lb./cu. yd. for loose dry sand, 2,980 lb./cu. yd. for moist sand and 3,200 lb./cu. yd. for wet sand.

The cycle time (complete operation) is an important factor in dragline usage and increases with the size of the equipment. The angle of the swing curve has a major effect. The following tabulation is theoretically applied to a 35-cubic-yard, walking-type dragline:

Angle of Swing Curve (degrees)	Swing Time (one way) (seconds)
72.5	16.0
90	18.0
120	21.0
150	25.0
180	27.0

and a typical cycle time would be

1.	drag and fill	21.5 sec.
2.	hoist, swing right & dump	16.0 sec.
3.	lower, swing left & position ...	20.5 sec.
	total cycle time	58.0 sec.

Dragline nomenclature is shown in Figure IV-3; the range abilities of a walking dragline are demonstrated by Figure IV-4 and Table IV-4.

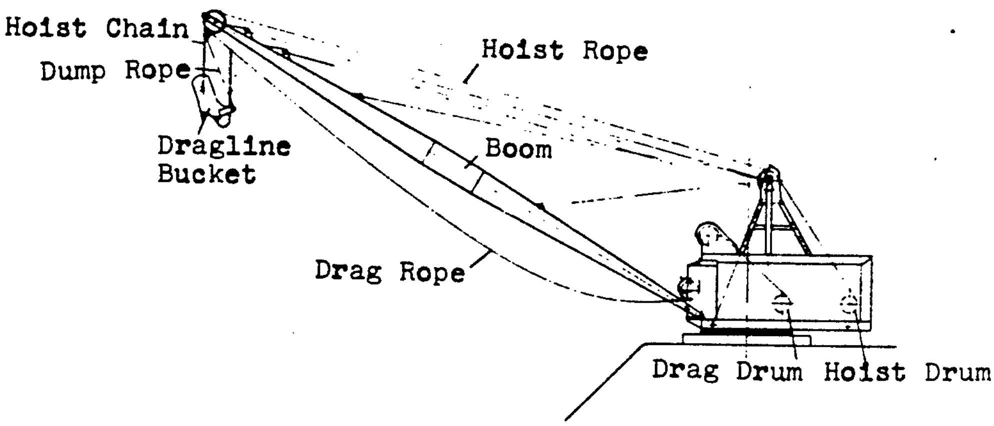


FIGURE IV-3: Dragline Nomenclature.

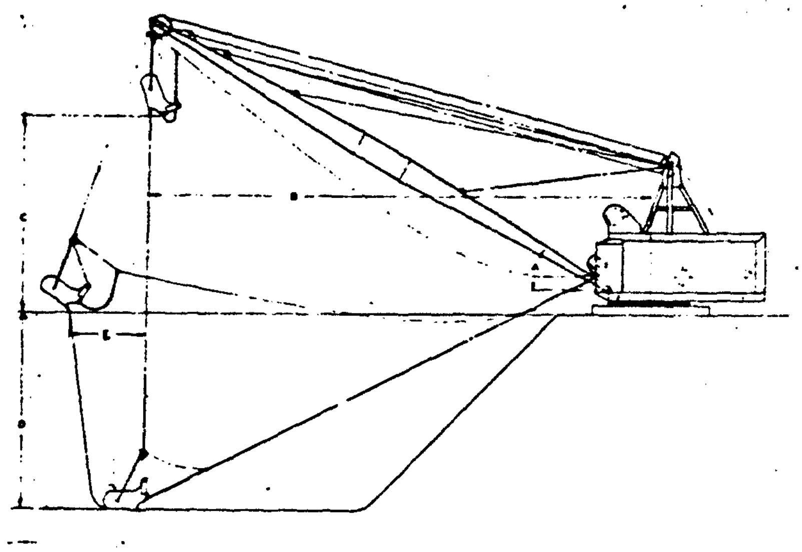


FIGURE IV-4: Range Diagram of a Walking Dragline.

TABLE IV-4: Working Ranges of 35-cu yd Walking Dragline.

Bucket Sizes Are Based On Material Weighing 100 lb/cu ft

Boom length	220'
Bucket size, cu yd	35
A—Boom angle (approx.)	30°
B—Dumping radius	211'-0"
C—Dumping height	81'-0"
D—Depth (std. cables)	110'-0"
*E—Bucket throw	35-55'
Maximum allowable load, lb	177,500
Drag pull, single line, lb	325,000

* Depends on skill of operator.

In Figure IV-5 a typical dragline is shown situated on a bench and in a position to work well below the bench level. In an ordnance removal or mine clearance application, the equipment should be offered some additional protection.

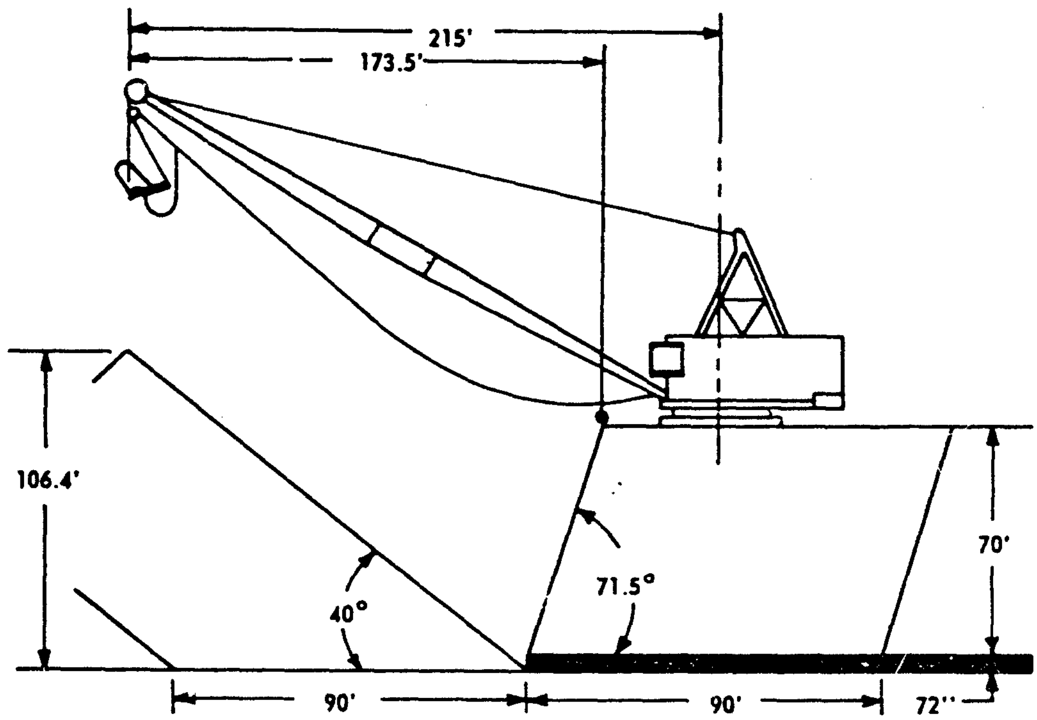


FIGURE IV-5: Dragline Working Below Grade.

6. Scrapers:

   consider when-

   a. overburden is moderately consolidated;
   b. weather is variable and adverse;
   c. high mobility is required;
   d. operational versatility is desired;
   e. reclamation is required in clearance plan;

f. little or no uphill scraping is required;
g. massive rock or sandstone is unlikely;
h. pushers are available to assist in loading.

7. Bucket-wheel Excavators:
consider when-
a. continuous operation is desired;
b. equipment can be built to job specifications;
c. lower power consumption is desired;
d. high production rate is required;
e. it is advantageous to work above or below grade level;
f. reclamation is required in clearance plan;
g. high capital investment can be borne;
h. overburden is not hard and is without large rocks;
i. simplicity of operation is desired;
j. flexibility is not a factor.

Figures IV-6 and Figure IV-7 illustrate bucket-wheel excavators employed in surface mining. In a possible range clearance excavation, the terrace cuts would be limited to 1 1/2- or 3-foot cuts.

8. Dredges:
consider when-
a. clearance is on lake or tidal lands where water is abundant;
b. deployment is not constrained;
c. mobility is not constrained;
d. low operating costs are desired;
e. good depth control is desired (within inches);
f. climatic conditions are stable during operation;
g. adequate water supply is available;
h. vegetation is not coarse or dense;
i. offshore storms, currents or obstacles do not preclude operation.

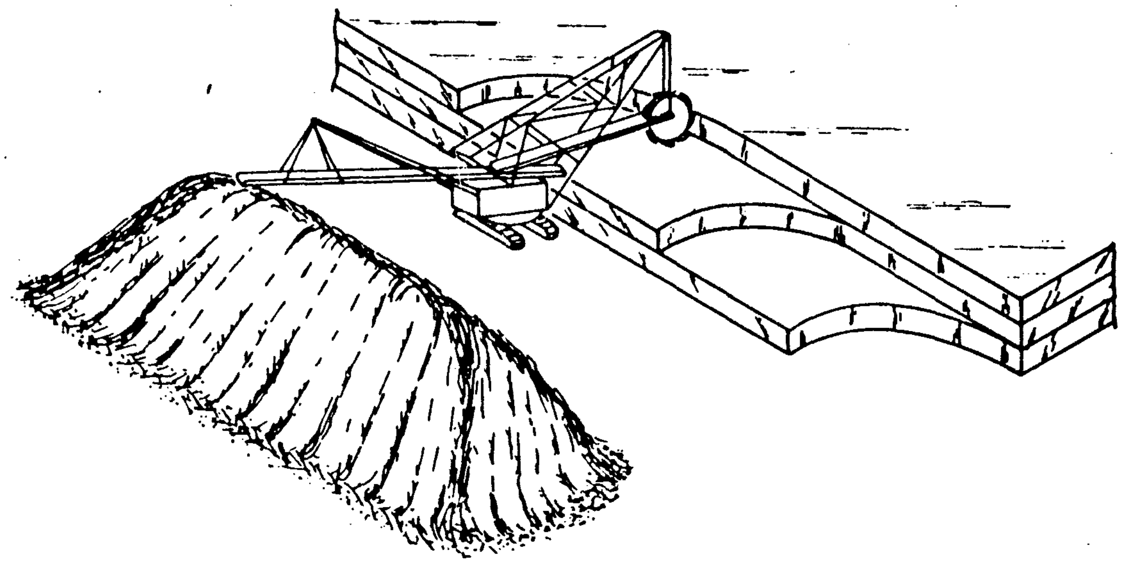


FIGURE IV-6: Lateral Block Cut Method.

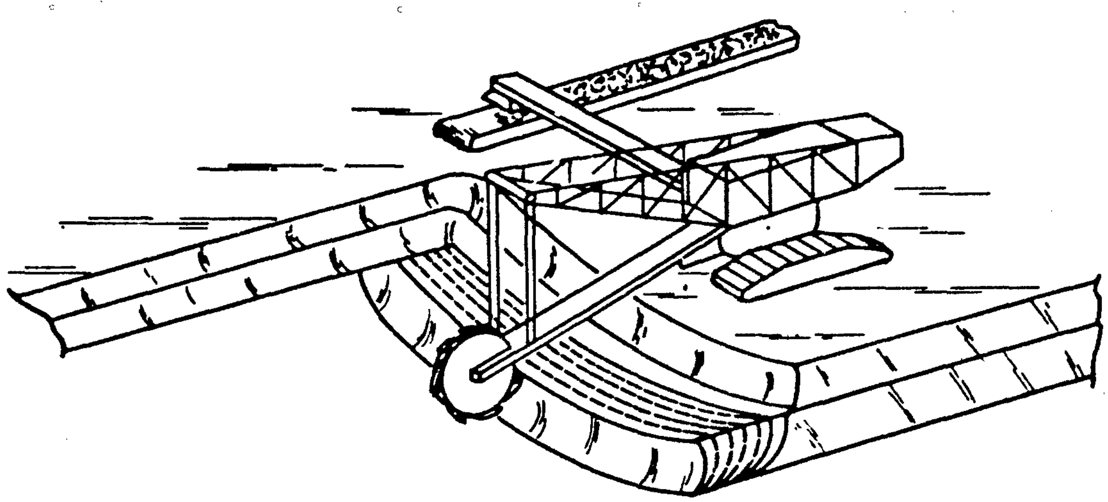


FIGURE IV-7: Deep Cut by Terracing Cut Method.

B. HAULAGE EQUIPMENT

The haulage equipment that could have application in range clearance operations are summarized by comparison in Table IV-5. When the range clearance plan indicates a requirement for transportation and dumping of overburden that has been removed for the search of buried ordnance, the following features of each type of equipment must be considered.

1. Bulldozers, Crawler-mounted:
   consider when-
   a. steep slopes must be negotiated;
   b. good mobility is not a factor;
   c. only short hauls are required.

TABLE IV-5: Summary of Haulage Systems

Conditions		Equipment									
			Scrapers					Truck			
		Bulldozers	Tractor-drawn Scraper	Under-powered, Rubber-tired Scraper	Full-powered, Single-engine Scraper	All-wheel-drive Scraper	Rubber-tired Tractor with Trailer Scraper	Rear Dump	Semi-trailer Rear Dump	Semi-trailer Bottom Dump	Conveyor
Material	Rough, blocky	1						1	1		
	Max. 36 in.	1						1	1		2
	Max. 24 in.	1	1	2	2	1	1	1	1	2	1
	Fines	1	1	1	1	1	1	1	1	1	1
Length of Haul	0– 300 ft	1	1	2	3	3	3	1	3	3	4
	300– 500 ft	2	1	1	2	2	3	1	2	2	4
	500– 1,000 ft		2	1	1	1	2	1	1	1	4
	1,000– 1,500 ft		3	2	1	1	1	1	1	1	4
	1,500– 5,000 ft				1	1	1	1	1	1	3
	5,000–10,000 ft				3	3	2	1	1	1	2
	10,000–15,000 ft						3	1	1	1	1
	15,000 ft plus							2	2	2	1
Ground Conditions	Good	1	1	1	1	1	1	1	1	1	1
	Wet, soft	1	1			3					3
Maximum Adverse Grade	+ 3%	1	1	1	1	1	1	1	1	1	1
	5%	1	1	3	2	1	2	1	2	2	1
	10%	1	1		3	2	3	1	3	3	1
	15%	1	1		3	3		1			1
	20%										1
	+20%										4
Flexibility under varied conditions	Good	1	1	1	1	1	1	1	1	1	
	Fair	1	1	1	1	1	1	1	1	1	3
	Poor	1	1	1	1	1	1	1	1	1	1
Daily Production Rate	Low	1	1	1	1	1	1	1	1	1	
	Medium		3	3	2	1	1	1	1	1	2
	High				2	1	1	1	1	1	1
Total Tonnage	Small	1	1	1	1	1	1	1	1	1	
	Medium		3	3	1	1	1	1	1	1	2
	Large				1	1	1	1	1	1	1

1. Should be considered.
2. May be considered.
3. May be considered under certain conditions.
4. May be considered, special situation.

2. Bulldozers, Four-wheel drive (rubber-tired):
   consider when-
   a. long hauls are required;
   b. good mobility is a factor;
   c. only moderate slopes need be negotiated.

The production rates for a four-wheel drive dozer are shown in Figure IV-8.

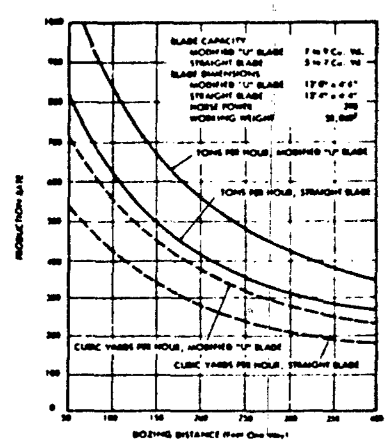


FIGURE IV-8: Four-wheel Drive Dozer Production Curve.

(Dozing conditions, favorable to level dozing; 60-minute working hour; material weight is 3,000 lb/cu yd.)

3. Scrapers, Crawler Tractor:
   consider when-
   a. the job is small;
   b. there is limited access to the clearance area;

c. power sources for larger units are lacking;
d. it is desirable that the equipment dig its own load;
e. transport speed is desired;
f. it is desirable to spread load;
g. mobility over long distance is not important;
h. surface conditions are adverse.

4. Scrapers, Rubber-tired Tractor:

consider when-

a. the job is small;
b. surface conditions are favorable to tire wear;
c. long hauls are required;
d. good mobility is desired;
e. there is limited access to the clearance area;
f. power sources for larger units are lacking;
g. it is desirable that the equipment dig its own load;
h. good transport speed is desired;
i. it is desirable to spread load.

Performance characteristics for tractor scrapers are shown in Figure IV-9.

5. Trucks, Conventional Rear Dump:

consider when-

a. large rock, bulky material, shale or combination material is to be hauled;
b. dumping is required in restricted areas;
c. hauling unit is to be subjected to severe loading impact;
d. maximum flexibility is required.

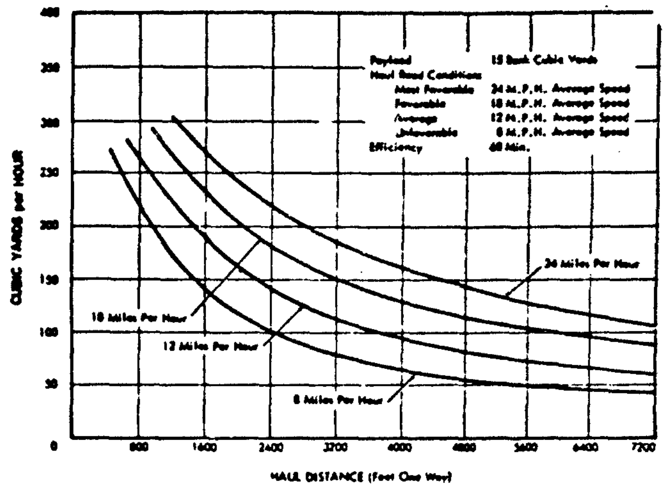


FIGURE IV-9: Typical Tractor Scraper Performance Chart.

6. Trucks, Rocker-type Rear Dumps:

   consider when-

   a. extreme maneuverability is required;

   b. traction is no problem, as on level or low-grade hauls;

   c. good horsepower-to-weight ratio is not required;

   d. prime mover provides versatility.

7. Trucks, Bottom Dump:

   consider when-

   a. material is free flowing;

   b. haul is relatively level, allowing high speed travel;

   c. dumping is unrestricted;

   d. long grades are not severe;

   e. maximum flotation of large low-pressure tires is required.

8. Conveyors, Pre-engineered:

consider when-

a. mass-produced system is amenable to job requirements;

b. maximum economy is required.

9. Conveyors, Conventional Stringer and Deck:

consider when-

a. custom engineering is required to meet requirements;

b. deep troughs are desired to minimize spillage;

c. versatility is desired in selection of power transmission for drive.

10. Conveyors, Wire-rope:

consider when-

a. low-weight design is desired;

b. good component accessibility is important;

c. considerable economy is required.

11. Conveyors, Shiftable:

consider when-

a. large excavators are used and it is desired to provide continuous haulage by following clearance operation;

b. it is desirable to avoid foundation or supporting structures;

c. clearance operation will permit lateral movement of conveyor system.

12. Conveyors, Regenerative:

consider when-

a. declined conveyor has application in mountainous areas and other adverse terrain;

b. loading is not so great that braking systems are overloaded.

13. <u>Conveyors, Compound</u>:

consider when-

a. undulating terrain demands special overland haulage application;

b. long conveyor flights are necessary.

14. <u>Conveyors, Cable</u>:

consider when-

a. belt needs only to support material, and withstand abrasion and impact at loading point;

b. lower speeds are acceptable;

c. lower initial cost but high maintenance cost can be considered.

Some insight into the design criteria and requirements for belt conveyor systems can be gained from Tables IV-6 and IV-7; actual design characteristics should be guided by the specific clearance operational requirements and by the other equipment utilized in the operation.

TABLE IV-6: Maximum Recommended Belt Speeds (FPM) for Standard Service.

	Maximum Speed	Belt Width (in.) 14	18	24	30	36	42	48	54	60	72
		Recommended Speeds									
GRANULAR FINES											
Minus 1-in. lump	1000	400	500	600	700	800	900	1000	1000	1000	1000
Occasional lump 10% Belt width	900	400	500	600	700	750	800	900	900	900	900
HALF MAXIMUM SIZED LUMP											
Rounded pieces	800	300	400	550	650	650	700	800	800	800	800
Abrasive, sharp	700	300	400	500	600	650	650	700	700	700	700
MAXIMUM SIZED LUMP											
Rounded pieces	650	300	400	450	500	550	600	650	650	650	650
Abrasive, not sharp	600	300	400	450	500	550	550	600	600	600	600
Abrasive, sharp	550	250	300	350	400	450	500	550	550	550	550
TO REDUCE BREAKAGE											
Friable ores	500	250	300	350	330	400	450	500	500	500	500
Coal	400	250	250	300	300	350	400	400	400	400	400
Coke	300	250	250	250	250	250	300	300	300	300	300
TO REDUCE DUSTING											
Heavy fines	300										
Light, bone dry fines	250										

NOTE: Belt speeds decrease with conveyor width primarily to prevent spillage, particularly at low belt tension. They may be increased if load cross sections are reduced.

TABLE IV-7: Suggested Minimum Belt Width in Relation to Lump Size Discharged between Vertical Skirtboards.

Type of Material	Ratio Belt Width to Lump Size	14	18	24	30	36	42	48	54	60	72
MAXIMUM LUMP SIZE (IN.) LONGEST LUMP DIMENSION											
Mine Run Material		Idler Troughing Angle 20°-30°									
Not more than 1% max. lump;	2¼	6	8	11	13	16	19	21	24	27	32
		Idler Troughing Angle 35°-45°									
Balance ½ max. lump, or less	2¼	5	6	8	10	12	14	16	18	20	24
Occasional Lump		Any Troughing Angle									
Not more than 6% max. lump; balance ½ max. lump, or less	3	5	6	8	10	12	14	16	18	20	24
Crusher Product Longest dimension	3½	4	5	7	9	10	12	14	15	17	21
Crusher Product, Fines Removed	4	4	5	6	8	9	11	12	13	15	18
Sized Material from Screening Operation	4½	3	4	5	7	8	9	11	12	13	16

Column heading over 14–72: Belt Width (in.)

NOTE: If these lump sizes are exceeded, special precaution may be required in chute, skirtboards, and elsewhere.

APPENDIX V

SUMMARY OF AREA CLEARANCE/MUNITION DISPOSAL ACTIVITIES IN THE UNITED KINGDOM

Area clearance and munition disposal operations in the United Kingdom were observed by the principal investigator during the period 11 to 16 March 1974. Information was gathered by discussions with key personnel and observation of actual operations at Maplin Sands, U.K. and Llanberis, Wales. All personnel contacted during this visit were most informative and provided utmost assistance at every location. Because of their daily exposure, both the officers and enlisted ratings assigned to bomb disposal units are keenly aware of the problems involved in the removal and disposal of impacted munitions. This visit provided a rare opportunity to observe and discuss procedures with EOD personnel who are actually engaged in a systematic sub-surface clearance of large, heavily contaminated areas.

DEFENCE EOD SCHOOL, CAMP LODGE HILL, CHATTENDON

The Defence EOD School was established as a joint service school in 1970 to meet the EOD training needs of the Royal Navy, Royal Engineers and Royal Air Force. The School is controlled by a tri-service committee and staffed by representatives from each service. The area clearance procedures taught at the school are similar to those employed by U.S. EOD units. There is a variation in search techniques because of the type of detection/location equipment used. Tab A contains a brief description of the 4C Mine Detector and the Forster Locators which are the primary search equipments.

The U.K. EOD clearance operations are normally divided into

three phases: (1) reconnaissance/planning, (2) search and clearance, and (3) disposal. They stress the importance of a thorough reconnaissance and detailed planning prior to the commencement of the clearance operation. The initial search is conducted visually, augmented by the 4C Mine Detector to detect surface and shallow sub-surface ordnance (up to 20" in depth). The 4C is very similar in construction and operation to the U.S. MK9 Ordnance Locator. The initial search is designed to remove the easily detectable ordnance and scrap ferrous material to facilitate subsequent detection and location of sub-surface ordnance. Detailed descriptions of the U.K. detection equipment, boreholing equipment and area clearance procedures are contained in the Defence EOD School course precis at the Naval EOD Facility Library.[1]

The U.K. EOD personnel have great confidence in the Forster, units in the field stressed the ease of operation, dependability, and low maintenance costs. The Forster substantiates the value of a visual meter readout to augment aural indications. Adjustable sensitivity settings also contribute to improved performance. Design detection ranges were stated as approximately 9 feet for a 50 kg bomb up to 15 feet for a 500 kg bomb. These ranges are of course dependent on ferrous clutter and the magnetic soil susceptibility. Interviews with user personnel at Maplin Sands indicated detection ranges of from 4.5 feet to 12 feet. Detections have been made up to 18 feet in isolated incidents. In a demonstration of the Forster under ideal conditions, using the borehole technique an operator plotted the exact depth and attitude of a 500 lb bomb casing. It was

[1] EODF C53-061. Trip Report with Notes and Precis, Defense EOD School NATO Course. TMC (DV) J.R. Blacmon. August 1973.

noted that most of the operators interviewed had been using the Forster almost daily for 1 to 3 years, which is probably the dominant factor in the detector's high performance rating. The Forster is considered to be superior to any locators currently in the U.S. inventory.

Specialized heavy equipments available for EOD unit training consisted of standard earth augers, an armored bulldozer, front end loaders, backhoes, and a Calweld hole driller, capable of drilling a 5' diameter hole in hard clay. There are no heavy equipments in inventory which might be considered as sophisticated earth movers or superior to those used in routine excavation work in the U.S.

MAPLIN SANDS, SHOEBURYNESS, ESSEX

Maplin Sands is the proposed site for an extensive new airport and port complex, approximately 49 miles east of London. The Sands are a tidal flat at the mouth of the Thames, covering an area approximately 14 miles long, varying in depth from 1 1/2 to 3 miles along the coast. There is a 10 to 13 foot tidal range which will require that the entire seaward area be diked and filled to a comparable level, prior to the installation or runways and airport facilities. This is to be accomplished by dredging fill from the port complex and sand bars at the mouth of the Thames. Maplin has been used as a test site and explosive "graveyard" since 1805. It is also currently in use as a bombing, naval bombardment and artillery range.

The 71st EOD Squadron Royal Engineers was formed specifically for the Maplin Sands clearance operation. There are two officers and 15 enlisted EOD technicians, augmented by a civilian work force of approximately 160 personnel recruited from the local community. The clearance force is divided into three platoons consisting of five EOD technicians and from 50 to 60 civilian

workers. The Squadron has a small staff cadre who function as a headquarters/administrative section, stores (supply) and motor transport.

Clearance operations are conducted seven days a week. The workers average about six hours a day "on-site" during the winter months and seven hours during the summer, dependent on weather and tidal conditions. All supervisory personnel are equipped with compasses and walkie-talkie radios because of frequent periods of low visibility and the unpredictable onset of heavy fog. There are no prominent navigation aids on the Sands, therefore vehicles are radio-equipped and maintain periodic contact with headquarters to be guided by the test range radar if required. The squadron has cleared about 1,000 acres in the past 19 months with approximately 11,000 acres remaining to be cleared. It is conservatively estimated that ten years will be required to complete the clearance with the work force presently assigned.

The clearance procedures are similar to those taught at the school. Initially, access roads into the various work areas are cleared and marked. Surveyors, working in conjunction with the surface clearance team, divide the area into 100 m^2 plots. Each plot is surface searched and cleared using visual search techniques in conjunction with the 4C Mine Detector. Upon completion of the surface clearance, search lanes are marked off approximately four feet apart. Subsurface search teams using Forster Locators (Type 4015) then search the area, marking potential targets for the recovery teams.

During the site visit it was noted that "diggers" followed closely on the heels of the Forster operator and commenced digging on his hand signal. The Forster operators appeared so well qualified that they could distinguish between spurious aural signals/indicator deflections and true targets in one pass.

A minimal number of "dry holes" were dug during the observation period. The consistent accuracy of the locator operators obviated the need for the more time-consuming location operations involving boreholing techniques. This somewhat phenomenal demonstration of the Forster capability can be attributed to the following factors:

- Most of the operators have used the Forster type 4015 almost daily for over a year -- their training level and familiarity with signal response to various targets far exceeds that of the occasional operator.

- A large majority of the ordnance has been located within 4 to 5 feet of the surface. Clearance to a depth greater than 5 feet would be impractical due to the mushy sub-strata at the 4-5 foot level, which has a quicksand-like consistency.

- The terrain and soil conditions are almost ideal, i.e. flat, sandy soil with very little ferrous contamination other than ordnance.

As the ordnance is located it is recovered, segregated and stacked for eventual loading on an LST for dumping at sea (see Tab B). The segregation and stacking is done manually with the help of a front-end loader as shown in Tab B. During the past 19 months approximately 50,000 items have been recovered, about 10,000 of these have been blown in place or demolished at the range; the remainder have been dumped at sea. Most of the heavy ordnance, in excess of 100 kg, is dumped at sea.

The only heavy equipment employed at Maplin were the trucks and front end loaders used for transporting ordnance to the demolition areas and staging sites. The relative utility of dozers and drag-line equipment had been considered but discounted on the basis of poor trafficability after the first cut. The

only unique equipment which had been employed was a "locator" sled. This sled was locally fabricated and consisted of an aluminum frame on wooden runners which could be towed by a Jeep-sized vehicle. Four Forster Type 4016 search heads were mounted on the frame in a manner which allowed for vertical adjustment. Four operators walk behind the sled equipped with earphones and the Forster deflection meter. (See Tab B). Contacts are marked by stake men on signal from the operators and digging teams move in to investigate the contacts. Although the sled increased search rates by a factor of ten, it is not currently in use due to a lack of manpower. Digging and recovery times govern the clearance rate, not detection. Because of this, the combination of a Forster operator and several diggers operating as a search/recovery team has proved to be more efficient.

Clearance rates were the subject of considerable discussion. Tab E shows clearance rate comparisons based on factual information obtained at Maplin, the ABCA briefing at the 1973 meeting and estimates contained in the 1973 NAVORD study.

LLANBERIS, WALES

Llanberis is a small village in northwestern Wales in the foothills of Mt. Snowden approximately ten miles south of Bangor. The area of interest was an abandoned slate quarry at the northern edge of town which was used as an ordnance disposal site after WW II. The quarry complex had been divided into four disposal areas:

I - General disposal, primarily used for burning of all types of ordnance

III - Used as dump area for incendiaries

IIIC - Mixed munitions and small arms

IV - Fuzes and detonators

The majority of the ordnance is U.S. and representative of every type of air drop munition used during WW II. Additionally, numerous types of projectiles, mortar rounds, pyrotechnics, grenades, depth charges and assorted British ordnance have been recovered by EOD personnel. There were no records available to indicate the types and amount of ordnance dumped into the quarry; the EOD personnel assigned would not even offer to conservatively estimate the total tonnage.

The Llanberis project is an RAF responsibility; there are ten EOD technicians assigned with a non-commissioned officer in charge. The decontamination project was initiated in December 1969 and the initial reconnaissance teams had to scale the sheer walls of the quarry by rappelling, in order to reach the contaminated areas. The EOD team, with the assistance of the Royal Engineers, has cleared key tunnels and constructed crushed slate access ramps leading into the primary disposal pits.

Area I, which was obviously the initial dump site and burning area, contains a conically shaped explosive residue slag pile which measures approximately 75 yards across the bottom diameter and is 150 feet high. Townspeople who witnessed the burning process have attested to the volcanic-like fires which burned for weeks. The core of the slag pile is composed of shrapnel and shell casings which have been welded together as a solid mass of metallic residue because of the heat generated during the burning process. Attempts to investigate this slag pile by digging or even selective dozing have been totally frustrated by the impenetrable mass of the molten core. The remaining areas represent an ordnance disposal nightmare. To envision the entanglement of assorted ordnance one must visualize the results of dumping truckload after truckload of ordnance over a sheer cliff 300 feet high into solid slate quarry pits. Tab C to this Appendix contains photographs of the disposal pits and recovered munitions.

To complicate the problem, each of the pits had flooded to varying depths which required the installation of pumps and a network of discharge lines. Water seepage and heavy rainfall have required continuous pumping operations since the inception of the clearance project.

As stated above access tunnels and roadways had to be cleared into each area. Once this was accomplished the EOD technicians commenced the dangerous and tedious task of sorting dud fuzed ordnance from the rubble. Fuzes, pyrotechnics, detonators, initiators/igniters, and exploders all had to be hand sorted and stacked for disposal. Demolition areas were established in each pit in a protected location to prevent sympathetic detonation and scattering of unexploded items. Because of the close proximity of the town and private homes an initial limit of 500 lbs per shot was established. Subsequent damage to homes has curtailed the single shot limit to 100 lbs. This limitation has impeded the clearance operation considerably and required that all bombs with an explosive weight in excess of 100 lbs be transported out of the pits to a staging area for subsequent trucking to a port area and transfer to a ship for dumping at sea. Prior to this limitation bomb casings were split with a focal point charge and the high explosive filler burned out using the No.3 MK I Incendiary Destructor. Although high-orders were infrequent and largely the result of experimentation with stand-off distances for the focal point charge, those which did occur invariably resulted in damage claims from local residents. The focal point charge is still used on U.S. 100 lb GP bombs with excellent success (99.5% low order). During the visit, discussions were underway with local town council members who desire to impose a ban against all burning and detonation. This ban, if imposed, will present an almost impossible logistics and explosive safety problem.

The heavy equipment used in this operation consisted of a small bulldozer, two backhoes with front loaders and three small, rubber-tired front end loaders which are capable of negotiating the tunnels and steep access ramps. The ten EOD technicians, supported by one administrative type and one civilian, work as three man teams for 14 day periods with four days off each two weeks. The teams are staggered so that the disposal operation is continuous throughout the year, weather permitting. Most of the technicians have been on the job since December of 1969. The following table is a partial but representative listing of items recovered through December of 1973, a three year period:

-40,982 items (approx 79 tons) consisting of:

primers	incendiaries	frag bombs
igniters	smoke pots	mortar rounds
detonators	pyrotechnics	GP bombs
exploders	grenades	cluster bombs
fuzes		depth charges

-A further illustrative breakdown:

21,000 - 4# incendiaries	200,000 - incendiary bombs
7,200 - exploders	78,000 - explosive scrap
1,759 - AN/M120 fuzes	12,000 - non-explosive scrap
771 - AAD bombs (U.K.)	

Even this partial listing is an impressive accomplishment for a ten man team, considering the hazardous and tedious working conditions. Best estimates available to complete the clearance are about two years. Increasing the size of the team will not have a significant impact on clearance rates because of the confined work areas. The lesson to be learned is -- don't dump live ordnance into quarries -- this may solve the current problem but it only compounds the future one.

RAF BICESTER, OXFORD

The Bicester RAF Base is the primary maintenance and retrofit depot for all RAF aircraft. It is also the home base for the 71st EOD (BD) Flight. The 71st EOD Flight provides mobile teams for all clearance jobs which come under RAF purview. The two major operations currently under way are at Llanberis and Orfordness.

Orfordness is an abandoned range about 40 miles northeast of London on the coast. Part of the base complex was a USAF early warning radar station which was closed in 1973. The range has not been used since 1960. Orfordness was designated as an artillery range in 1914. Subsequently an instrumented test and bombing range was installed and the base complex became an RAF responsibility. The range is contaminated with every type of British military ordnance developed since WW I, including Hale's rockets, Cooper bombs, small arms, ASW bombs, Research Lab bombs (experimental), projectiles, cluster bombs, pyrotechnics, incendiaries, etc. The majority of the intact items are duds.

The soil composition is rather unique: the top strata is composed of "shingle" (rocks 1 1/2" to 2" in diameter, see Tab D) down to a depth of five to eight feet. Under the shingle is hard, so-called "London" clay; very little ordnance has penetrated to the clay. Although EOD teams have routinely surface cleared this range over the years, it was not until the USAF radar station closed in late 1973 that a clearance team was assigned full time. A ten man team is currently working the range with a small hard rubber track dumpster. It was noted that all UK EOD units prefer to use ten man teams for most clearance jobs and their squadrons are organized accordingly. The 71st EOD Squadron assumes a one acre a day per ten man team as a normal surface clearance rate.

The team at Orfordness is conducting clearance operations using procedures identical to those at Maplin Sands,i.e. surface clear 100 m^2 area, lay out lane markers, then dig on Forster Locator contacts as they occur. The team is currently averaging 1/4 acre per 8-hour day. This is almost double the rate at Maplin Sands although digging is much more difficult. This is accounted for by the fact that the amount of contamination per acre has been far less than Maplin, as Orfordness was not used as a dumping ground.

GENERAL OBSERVATIONS

A. Despite the fact that U.K. EOD technicians receive far less training than their U.S. counterparts, their required ordnance background and extensive, almost daily, experience seems to counter the formal training deficiency. Other than the IED problem, their primary employment equates to ordnance handling in a unique environment. (Maplin/Llanberis). The knowledge and attitudes of all EOD personnel interviewed was most professional.

B. Sub-surface detection/location capabilities are superior to U.S. EOD units. This is primarily attributable to the expertise of the Forster Locator operators acquired through almost daily use. There is no substitute for training and operator confidence in equipment.

C. Most of the EOD clearance equipment is similar to U.S. and of the same vintage. Their approach to the problem is simple, straightforward and practical. They consider manpower as the principal and governing resource.

D. The safety precautions observed by British EOD technicians might appear to be casual in contrast to U.S. standards. In consideration of the magnitude of the clearance problem at Maplin Sands, Orfordness, and Llanberis there is no practical

alternative. Although their procedures might be classified as falling into the "calculated risk" category, based on their past safety record -- no accidental detonations at either location -- the techniques and handling methods cannot be subjected to criticism. The following rationale was developed in discussions with the EOD technicians:

- With the exception of large lots of ordnance which were dumped (unfuzed) throughout the entire area, the range can be divided into sections which contain similar types of ordnance. This is largely a factor of the era (Civil War, WW I, WW II) in which the ordnance was developed and the range of various weaponry which has been tested. Air drop zones and naval bombardment ranges have also been fairly well identified. (Maplin/Orfordness).

- The search teams are totally familiar with the area and the numerous types of ordnance encountered/recovered. (The ability of the EOD officers to identify ordnance encrusted with several decades of sea growth was most remarkable and indicative of their experience).

- EOD officers stated, that from their observation the fuzing circuitry, particularly in ordnance which was WW II vintage or earlier, has been deteriorated by salt water corrosion to the extent that it could be safely handled and transported for dumping at sea. (Maplin)

- When ordnance is encountered which appears to be in "operable condition" (not defined) identification procedures apply and a determination is made as to the proper RSP. (All areas)

E. In discussing problem areas and recommendations for improved range clearance techniques the following areas were highlighted:

1. The need for more mobile (all terrain) vehicles and improved handling equipment,
2. Additional manpower requirements,
3. Difficulties encountered in obtaining records and literature on old ordnance,
4. The impact of ecology constraints and potential damage claims, and
5. Problems involved in disposing of ordnance in densely populated areas

F. It is noted that the problems faced by the EOD technician in the United Kingdom and probably any other country are practically mirror images of our own.

TAB A

U.K. EOD DETECTION/LOCATION EQUIPMENT

MINE DETECTOR 4C

The 4C mine detector is a hand-held portable unit for detecting ferrous metallic objects on the surface and just below the surface. The unit consists of a search head, telescopic pole, amplifier unit and headphones.

The 4C is a self-contained field generator. Using electrical energy supplied by a battery, two search coils are balanced within their own magnetic field. Any interference or distortion of this field by another will cause the coils to "overlap" and give audible indication of the unbalance. The range is extremely limited, 20 inches being the maximum detection depth of a British Mk VII anti-tank mine which is of all metal construction. Detection depth is dependent directly upon the amount of ferrous material used in the construction of the ordnance.

Forster Locator Type 4015

The 4015 Forster locator is a German-made, battery-powered, man-portable locator designed to detect and locate ferrous objects buried in the ground. The Type 4015 consists of a detector probe and visual indicator, control box, amplifier, headphones (audible indication), and folding handles.

The detector probe contains two pairs of electromagnetic coils, mounted 40 centimeters apart. One coil in each pair

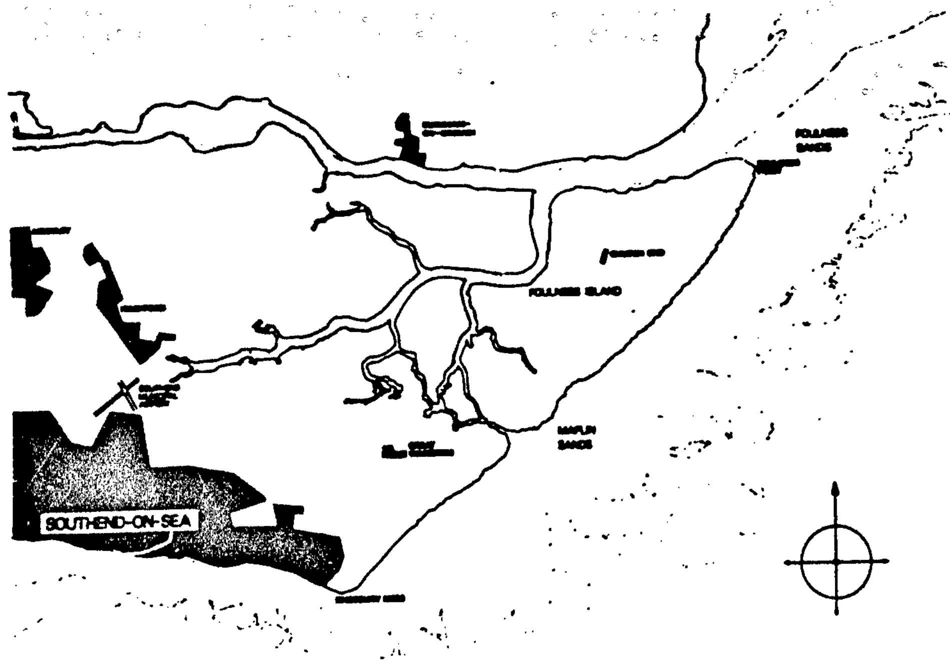
has a fixed magnetic field, whereas the other coil is variable. The coils are connected through a flux gate. Magnetic fields are electrically balanced so that the difference in induced magnetism is zero. When the earth's magnetic field is intensified or distorted by a ferrous object, the field of the variable coil will be affected, causing an unbalance which can be measured, calibrated, and made to give an audible signal.

Controls include a six-position sensitivity switch plus a sound control and compensating switch. The indicator dial is located on the probe handle and is graduated into 15 divisions on either side of zero. Theoretical detection ranges vary from 9 to 15 feet depending upon the size of the object.

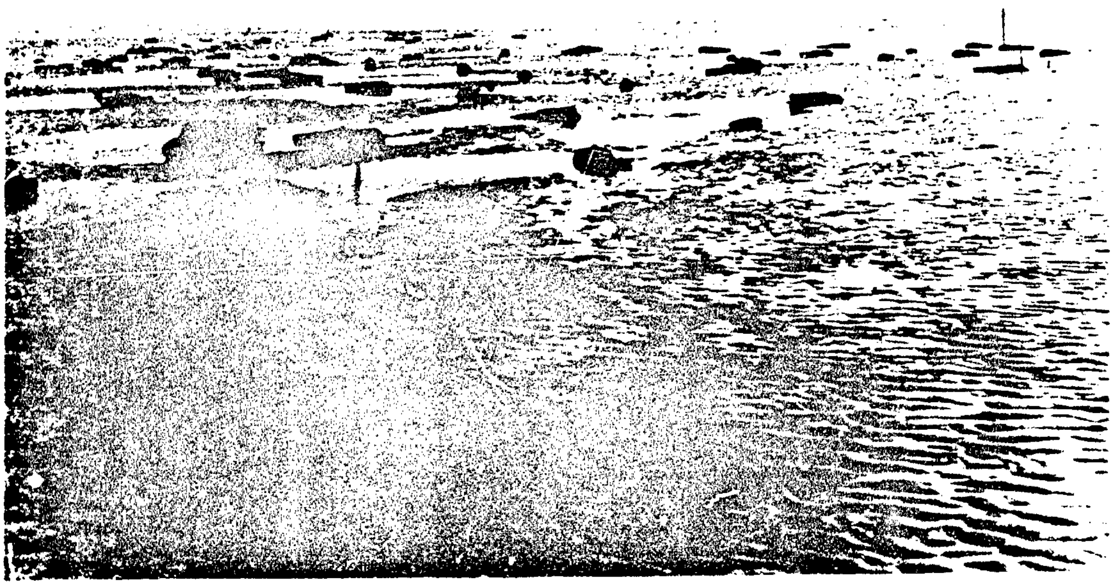
FORSTER LOCATOR TYPE 4016

The 4016 Forster locator operates on the same principal as the 4015. It was originally designed for detecting ferrous objects underwater; after exhaustive tests it was found well suited to use as a borehole locator. The detection probe is attached to 200 feet of cable which is reinforced by braided cord knotted at one foot intervals. The visual indicator (no aural) and batteries are housed in the transit case. Designed for two-man operation, the 4016 has a horizontal detection range of 9 to 15 feet depending upon the size of the object.

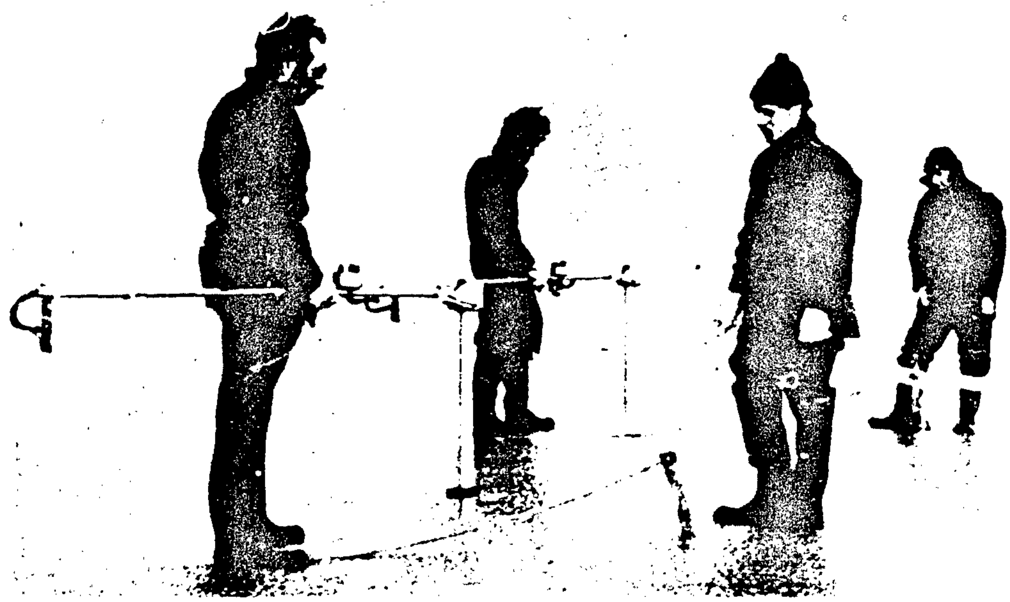
TAB B: MAPLIN SANDS CLEARANCE OPERATIONS



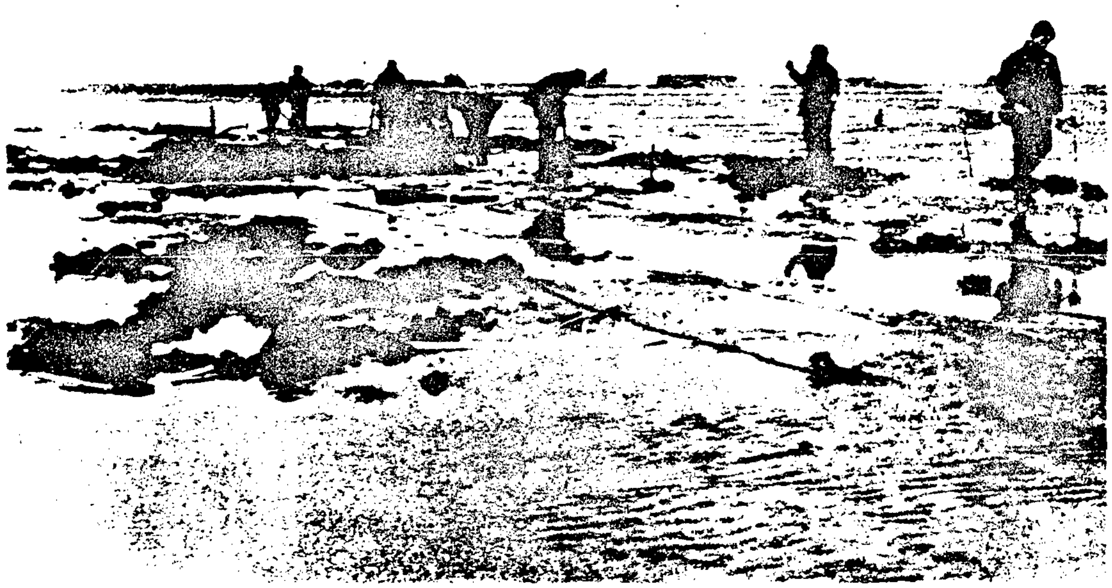
Maplin Sands



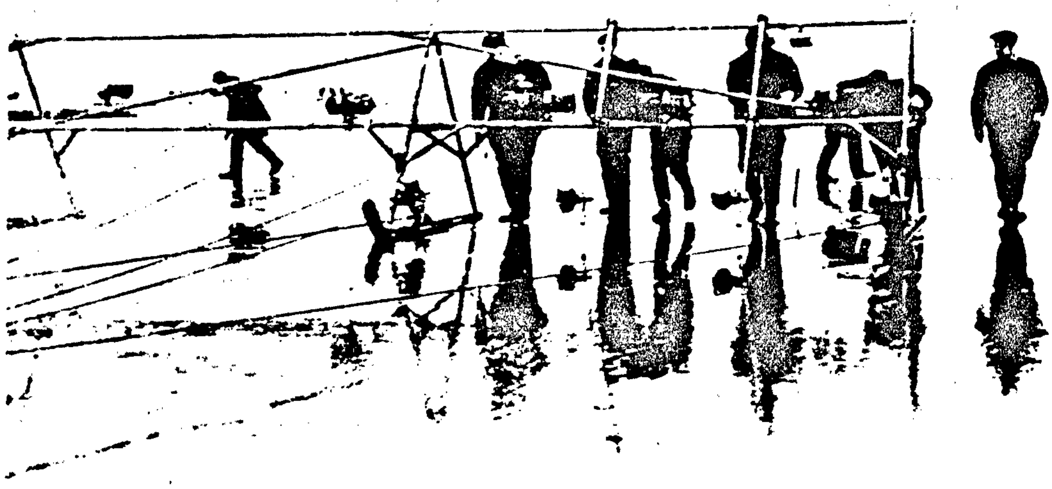
Maplin Sands Contamination



Forster Locator Operation

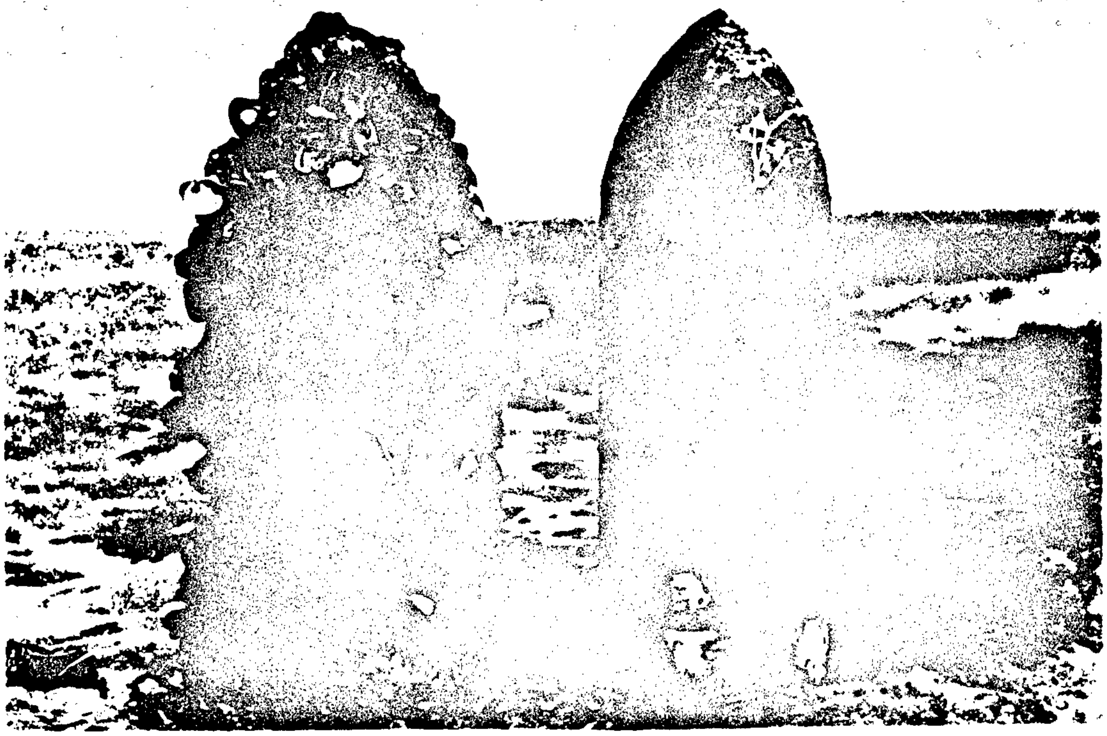


Detection/Recovery Operation

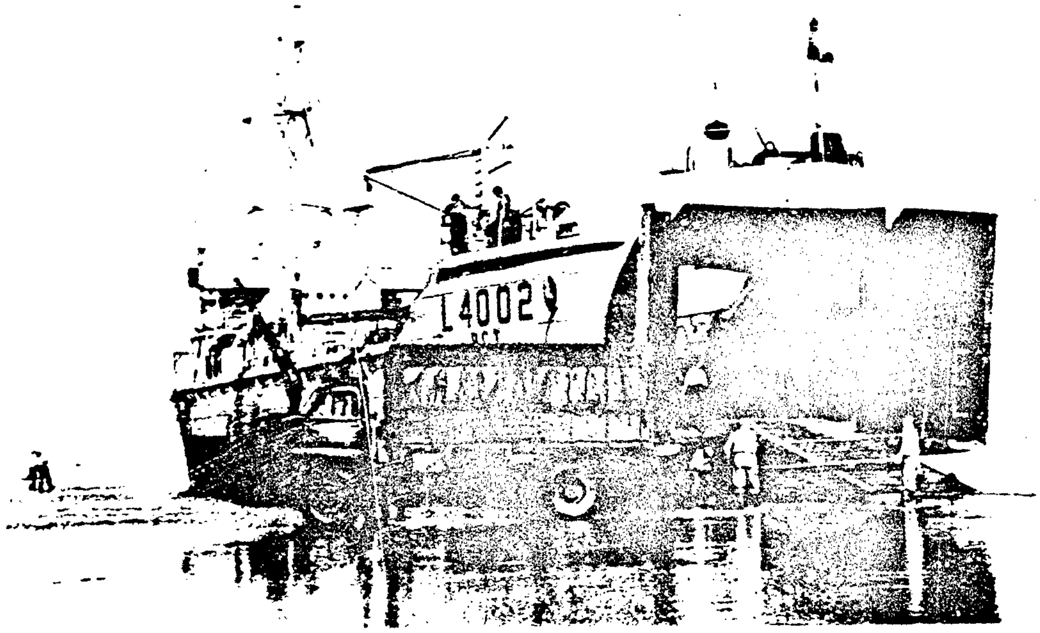


Forster Detector Sled

[illegible] Operation

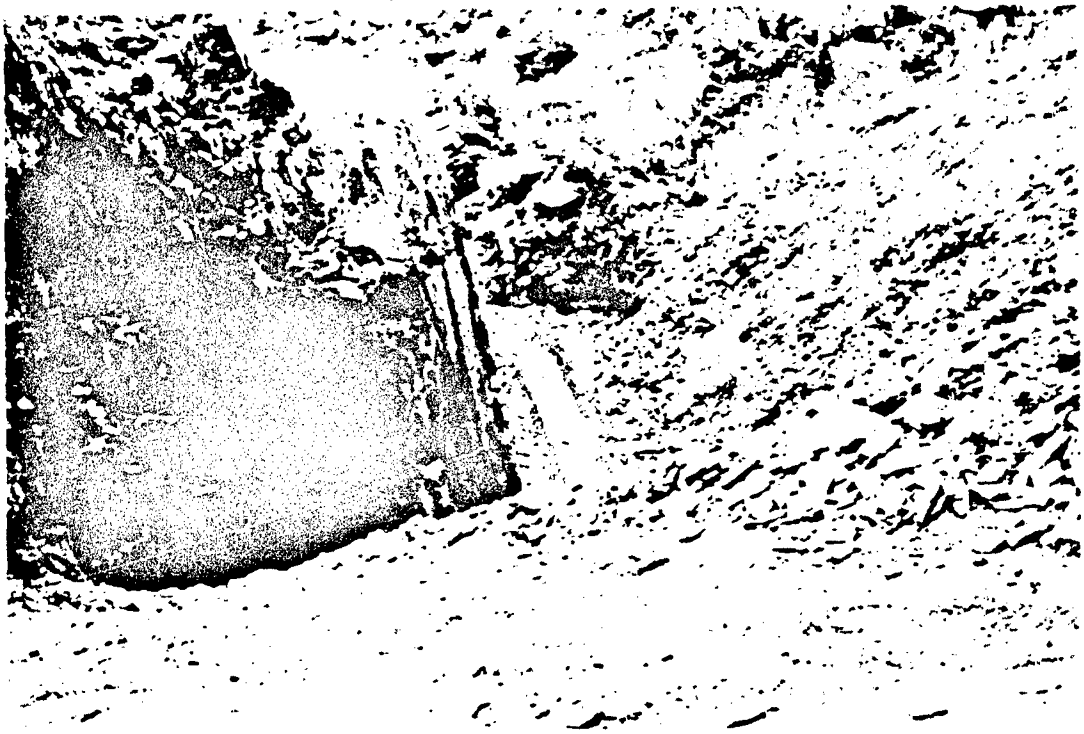


Typical Projectile Encrustation

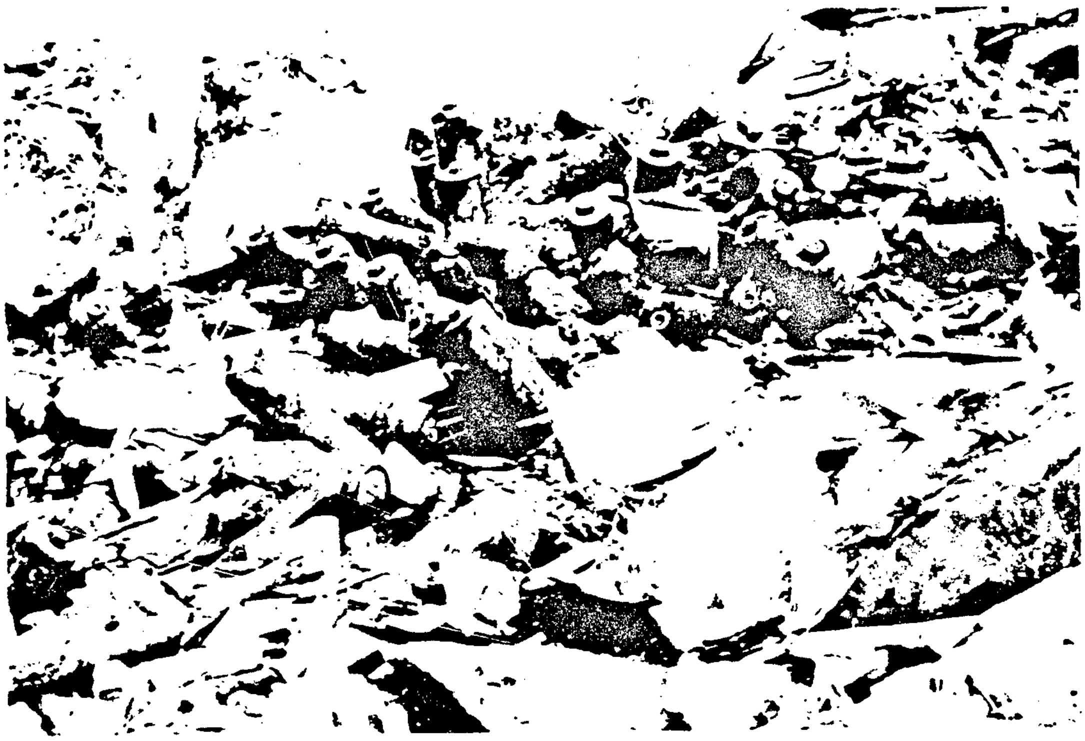


Loading into LST For Sea Dump

TAB C: LLANBERIS QUARRY CLEARANCE OPERATION



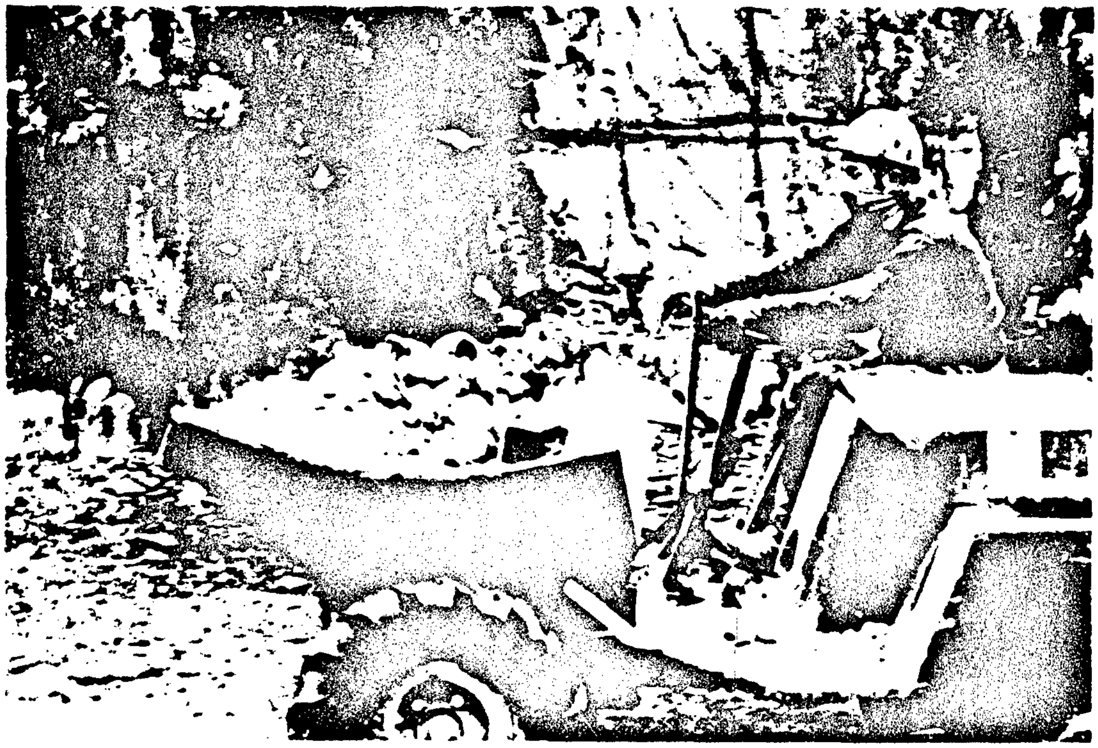
Access Road into Quarry



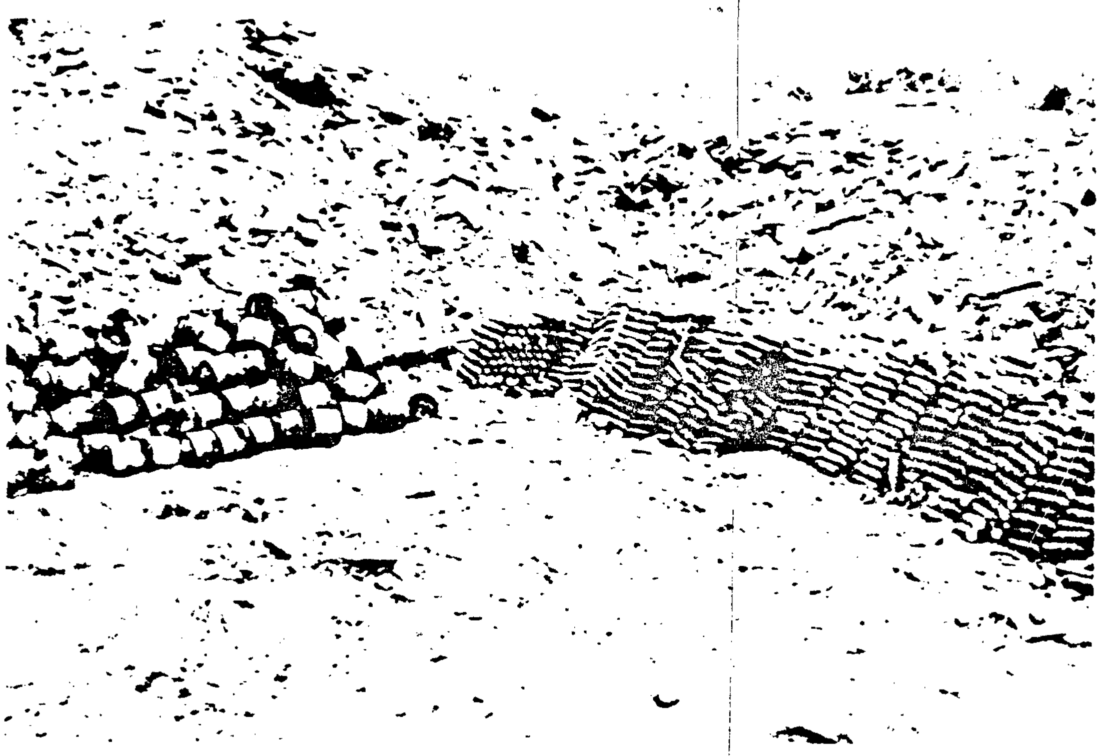
Typical Dump Area

Segregation Area

Removing Ordnance from Quarry

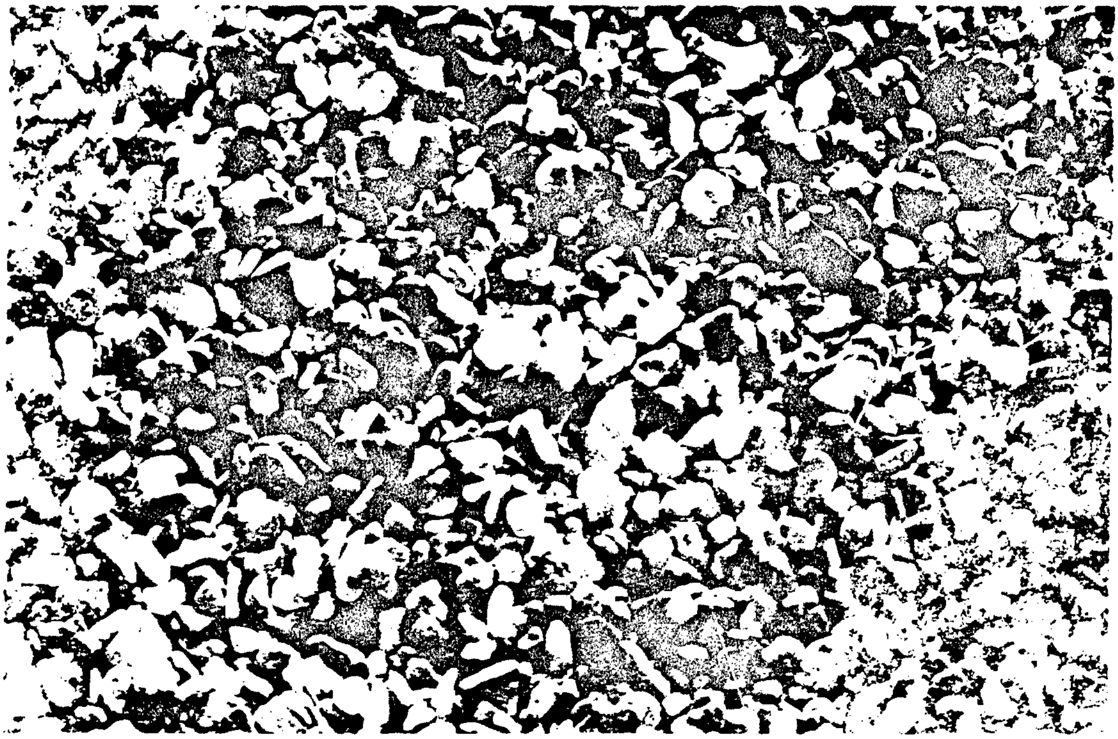


Front End Loader



Stacking Area

TAB D: SURFACE COVER AT SHOEBURYNESS RANGE



Shingle Surface Cover at Shoeburyness

SCITEK, INC.

TAB E

CLEARANCE RATE COMPARISONS

PERSONNEL	DEPTH (ft.)	TIME SPAN	RATE
MAPLIN SANDS, U.K. (Actual clearance rates)			
200	4.5/5	7-day week	19.8 Acres/week
200	4.5/5	50 weeks	988 Acres/year
10	4.5/5	5-hour day	0.101 Acres/day
CONVERSION TO 5 DAY WEEK			
10	4.5/5	7-hour day	0.705 Acres/week
10	4.5/5	7-hour day	0.141 Acres/day
10	4.5/5	5-hour day	0.101 Acres/day
1973 ABDA BRIEF (for comparison purposes)			
212	5	5-hour day	494 Acres/year
10	5	50 weeks	23.3 Acres/year
10	5	5-day week	0.466 Acres/week
10	5	5-hour day	0.093 Acres/day
U.S. NAVY STUDY ESTIMATES			
19	6	8-hour day	504 Acres/year
19	6	8-hour day	2 Acres/day
10	6	8-hour day	1.05 Acres/day
10	6	5-hour day	0.658 Acres/day